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Publisher's Letter

The economics of hybrid solar systems

Our report on a hybrid solar system in the October 2015 issue has created a great deal of interest among our readers. People are particularly interested for a number of reasons and two of those reasons are the escalating cost of electricity and the daily service charges levied by the energy retailers. These daily service charges are usually regarded by consumers as unjustifiably high, especially since they have been increasing at a much higher rate than the actual energy tariffs. So much so that many readers have entertained thoughts of going off-grid altogether.

And that brings us to the hybrid solar system described in October. Compared to any normal domestic grid-tied solar system, this is a large system indeed, with a particularly large installation of deep-cycle lead-acid batteries. Such a large battery bank is absolutely necessary if the system is to be able to cope with a period of rainy days when the output from the solar panels is likely to be severely curtailed and of course, to cope with normal power demands at night.

No matter which way you look at it, the system is a credit to the owner, Geoff Woodman, who has really been a pioneer – there are not too many other domestic installations of this size in Australia and of those that have been installed, most have been by owners who are very well-heeled and not really concerned with the all-up cost.

However, those who are not so well-heeled need to look very carefully at the economics of such an installation before going ahead. This is particularly the case where the proposition is to go completely off-grid because that requires an even larger and more costly battery bank.

Two correspondents in this month's Mailbag pages have been quite forensic in their analysis of the economics of Geoff Woodman's system and if you read their letters carefully, the only logical conclusion is that the economics simply don't add up.

You can certainly question some of the assumptions in the two letters. For example, I think their assumptions about solar panel life and decline in output are overly pessimistic. However, there is no doubt that solar panel outputs do decline and more so if they are never cleaned. Nor can you expect that a bank of solar panels will never need any maintenance or repairs. Just think about how individual solar panels or their bypass diodes may fail. What's more, the connections will almost certainly be subject to corrosion and the isolating switches or solenoids may fail or go high in contact resistance.

From stories in our Serviceman's Log pages, we already know that the grid-tied inverter is the weakest link in a typical domestic system and that is not likely to be any better in a larger hybrid system which will employ several inverters. Finally, there are the storage batteries and these definitely do have a finite service life. Lithium batteries are likely to be a lot better but they are not a mature technology yet and no-one really knows how reliable they will be in the long term.

Some readers may quibble about the likely return on investment and opportunity cost. Some may not fully understand how the calculations on such an investment are made – they are similar to the calculations for principal and interest payments on a home loan but in this case you would start with a principal amount which is invested, say $50,000 at 5% after-tax, so you earn $2500 per annum. Then you deduct the cost of energy for the year, say $3000, to end up with $49,500 and then the cycle repeats each year so that your principal is gradually reduced. But that ends up being a more economic proposition than spending that money on a solar hybrid system.

Ultimately, no matter how optimistic and environmentally conscious you may be, and how you may twist the assumptions about return on investment, there is no avoiding the conclusion that hybrid solar systems are simply not an economic proposition at the present time. Furthermore, those costs will need to be substantially reduced before such installations become economically attractive.

Leo Simpson

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Cheap PIC32 programmer is welcomed

The Cheap PIC32 Programmer article in the November 2015 issue was just what I was looking for. Great stuff, SILICON CHIP! The PIC32 is a very interesting chip, apparently based on MIPS commands originally created 34 years ago in 1981.

As an assembly programmer (yes, C is great but you really need to understand assembly to make C work), I found it difficult to find assembly instructions clearly defined in the way the PIC16 and PIC18 series are, where there are separate chapters on assembly code.

From what I found, PIC32 data sheets only have a non-descriptive list of commands that relate back to a broad MIPS standard. I was wondering if SILICON CHIP knew more about the PIC32 instructions and if they could elaborate on these, maybe in a future article. The PIC32 is a DSP type processor and it may also justify including within the article something on DFT and FFT code.

Hamish Rouse,
Mt Martha, Vic.

Sidereal clock information on website

With respect to my Sidereal Clock design published on page 73 of the November 2015 issue, I have put some documentation on my website, at **www.cashin.net/sidereal**

If people want to know the soldering points on the GPS module, there's a picture. There's also a description of how the program works.

Alan Cashin,
Islington, NSW.

SMD drawbacks & merits

I refer to your ECG project that appeared in the February 2005 issue and the revised version presented in the October 2015 issue.

For those of us who find soldering SMDs challenging, it's a shame that you insist on using them even when leaded versions are available for all the parts, as is the case for the Mk2 version of this project. However, having read your response to another reader's comments (page 94, October 2015), I now understand the philosophy behind it – future-proofing PCBs, longer term availability of parts and lower cost. Of course, for the more complex circuits, the smaller footprint of these SMDs reduces the size of the PCB.

Already some SMDs can only be purchased in quantities of three or more and I fear that one day the suppliers won't "cut the tape" at all and only supply the whole reel! Then hobbyists would be totally dependent on kit suppliers and SILICON CHIP to supply parts, as they alone can afford to buy in bulk.

Tony Barrett,
Queenstown, Tas.

Small portable radios lack a ground plane

I have been following readers' attempts to receive AM and FM broadcasts when they are in weak signal areas with great interest. I too have suffered with poor FM reception for some 12 years. I like to listen to ABC News Radio for 12 hours each day. My

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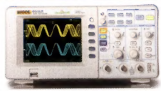

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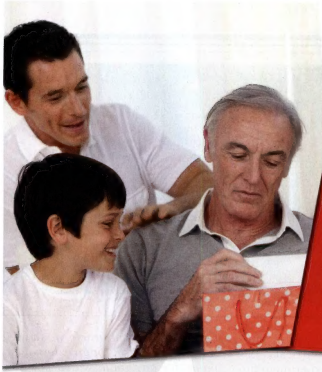

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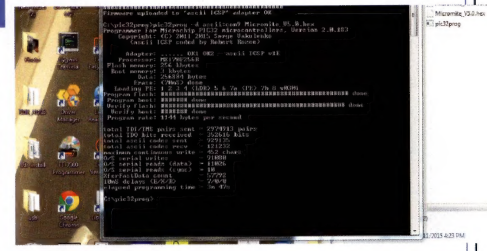
Mailbag: continued

Success with low cost PIC32 programmer

I have just completed a version of the low-cost PIC32 programmer described in the November 2015 issue of SILICON CHIP. I tested it and programmed a 28-pin PIC32MX170 with MMBasic Ver5.0 and it works! All this on the same day I purchased your great magazine. I have attached a screen shot of the first run.

Max Joiner, VK3AMW, Lancefield, Vic.



difficulty stems from my home being some 10km from the transmitter, with a large hill situated directly in the transmission path.

In an effort to overcome my poor reception problems, I recently purchased a Bush BR25 DAB+ radio, which was the physical size and in the price range that I wanted. It has a 43cm telescopic antenna. To my annoyance, on some days I was able to receive crystal-clear reception on FM but on the next day there could be so much hash, that I had to turn the radio off and listen to CDs all day. On the following day the reception could be crystal-clear again.

I had situated the radio on the end of my wooden kitchen bench, up against the wall, in a convenient spot where I could adjust the controls from the kitchen or from the living room. Recently, I was having poor reception and in desperation I moved the radio about half a metre. I sat it on top of the metal edge of the draining board and found the reception suddenly became crystal clear. It seems the radio must pick up the signal via capacitance from the metal draining board or perhaps the signal grounding had improved.

I had been trying to improve the reception for many months by extending the antenna, adjusting its orientation and moving the position of the radio in the room, all to no avail.

The radio is powered by a separate plugpack power supply with a 1.6-metre lead, which outputs 5V to the radio. Fortunately, my power supply is plugged into a wall-mounted GPO, so there is less danger of standing a 230VAC appliance near water. But I would like the radio well clear of the sink, so I will need to experiment further with this ground capacitance coupling or whatever it is.

This revelation jogged my memory back to living overseas in the 1950s, when I read of an antenna project for people living in apartments, where it was difficult to install a "Long Wire" antenna, for AM reception. The project involved gluing a sheet of aluminium foil to one side of an unwanted 45 RPM record. A thin lead was then attached to the foil, the other end of which was fastened to the radio antenna. A second old record was then glued on top of the foil.

This "Pancake" was then placed under a telephone. Because all the telephone wires overseas were suspended above ground, the telephone radiated excellent RF signals to the capacitively-coupled foil, which then travelled to the radio antenna via the lead. I guess our modern technology has advanced too far these days for this 60-year old project to be of any benefit to us.

Tony Farrell, Kingscliff, NSW.

Comment: the fact that your reception improved when on the draining board seems to indicate that the radio's whip antenna needs a ground plane in order to work well. Rather than your solution, why not simply try sitting the radio on a sheet of aluminium or any other conductor? Earthing the "ground plane" is also likely to improve the result.

You may also be interested in the November 2015 article on a DAB+ antenna. In that same article, we showed how to fit a socket for an external antenna for any radio which has FM/DAB+ reception. While you may not have any possibility of DAB+ reception at your location, you could consider constructing the 5-element FM antenna featured in the October 2015 issue.

Risks from Heart Rate Monitor

I wanted to draw your attention to the inherent risks in the latest heart rate monitor project. As a medical product designer for many years, the greatest risk from any project is patient leakage currents, especially so when connections are made to the body in the vicinity of the heart. The commercial product limits for such product types are in the microamp region and are measured for DC and AC currents.

The simple warning in your article to run the project on the laptop on batteries is basically asking for problems as I expect you may not have measured leakage currents to the patient connection. Even on batteries, significant leakage currents can result. The possibility that a user may still have a wired network connection or an external printer connection also needs to be considered as potential risk factors. If the user touches anything else whilst connected, this may also cause increased currents to flow.

So as mitigation to risk I would suggest you provide a correction to the warnings:

(1) Operate this project from a laptop PC ONLY running from batteries, with no mains charger connection – remove

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Mailbag: continued

Focus on fuel economy, not emissions

In regard to recent claims that VW caused the measurement in government tests of lower emissions of their diesel cars than was the reality, I would like to comment as follows.

It is claimed that software in the engine management system could detect when an emissions test was being done by recognising the standard conditions of the test. When this happened, emissions controls were activated but at other times such as normal driving conditions, they were deactivated, to some extent resulting in excessive emissions.

The legalities or otherwise of what happened will vary between countries, although it is clear that the cars passed all the required government testing, at least in letter of the law if not its spirit.

One consequence of deactivating or reducing the amount of emissions control resulted in the production of more nitrogen oxides (NOx). Pollution due to NOx was one of the reasons emissions controls were enacted in cars in Western countries in the 1960s in the USA and other places in the 1970s, as NOx (and unburned fuel) was a major contributor to photochemical smog in geographically susceptible cities such as Sydney and Los Angeles or cities susceptible due to population density such as London and Paris.

An advantage of diesel cars is that they can get about 30 percent more fuel economy than a petrol car although the price differential of the fuels needs to be taken into account.

A disadvantage of diesel engines, however, is that they produce much more NOx due to their higher combustion pressure than is the case for petrol engines, which allows more nitrogen and oxygen, both from the intake air, to combine during combustion.

In modern petrol engines, NOx is controlled by a so-called 3-way catalytic converter which, among other reactions, causes NOx to be converted to nitrogen and oxygen.

This strategy does not work for diesel engines due to a high level of oxygen in the exhaust which would immediately re-react to produce more NOx. Diesel engines typically use a 2-way catalytic converter to control emissions apart from NOx.

Control of NOx in diesel engines requires various strategies such as reduction of combustion pressures, exhaust gas recirculation and/or the addition of a chemical called "diesel exhaust fluid" to the exhaust (such as urea) which converts the NOx to nitrogen and oxygen with the use of an additional catalyst in a system known as "selective catalytic reduction".

This chemical has to be refilled at regular intervals and is available in Australia, one brand being AdBlue which is used in some diesel vehicles. Consumers complain about the cost and inconvenience of such diesel exhaust fluid products.

The engines affected in the VW scandal, the EA 189 in 1.6 and 2.0-litre variants did not use the diesel exhaust fluid system and it is claimed they did not have time to retrofit 2009 model year cars with the system to meet US emissions tests, hence the "cheat".

Whatever VW's motivations, the outcome was that it benefited the consumer. More NOx means higher combustion temperature and/or pressure and therefore more efficient combustion. That means more power and better fuel economy for the consumer.

NOx is a natural by-product of lightning and is important for soil fertility. Its only adverse effect as an exhaust product in typical concentrations is in certain cities susceptible to photochemical smog. NOx should be controlled in such cities but not elsewhere.

Arguably, VW's strategy resulted in more powerful and fuel efficient cars. With NOx emissions controls activated, power and economy will be reduced and ironically more CO_2 (not a real problem but that's another story) will be produced to obtain the same power output (unless the diesel exhaust fluid system is used). Since NOx is not a real problem outside of affected areas, consideration should be given to activation of NOx controls using GPS to determine if the car is in a susceptible area.

Dr David Maddison, Toorak, Vic.

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the plug from the computer and the mains power plug.
(2) Disconnect all external cable connections whilst in use – network, printer etc. Do not touch any other product, appliance or accessory whilst in use.

Some time ago you had a mains isolation scope accessory project and having this as either a front-end or back-end to this type of project would eliminate any risks but increase cost and complexity as usual.

I note your letters related to EMI. This is what I do these days for many Australian product developers and manufacturers to fix EMI/EMC issues, as so many designers generally have limited knowledge of EMI issues. The two sides are:
(1) Emissions – which is the general subject of your letters and involves noise being seen on TVs or heard on radios. ACMA is keen to address this as such emissions are in contravention of our local laws. Problems can be reported to ACMA for follow-up action.
(2) Immunity – this is less recognised but equally important. Product functional reliability and safety is the issue as well as the potential for damage.

Most products I see work as intended and do their thing very well. As soon as I measure the emissions, there is generally a problem, and as soon as I start testing immunity, the products can be seriously affected. My advice is generally that you must comply with emissions limits by law and for immunity, testing and fixing gives confidence that products will work in any environment and there will be no customer complaints – as soon as costs are mentioned in recalls, action is taken.

Many product standards now require immunity testing as well. For your letter writers, my advice for lighting products in particular is to only purchase well-known brands; preferably of European brand as these are usually CE marked and, as they are for sale in Europe, must have appropriate EMI reports and so we benefit. The very cheap lamps may have a CE mark but unfortunately are not always tested – as the production cost is so low, there is no margin for testing.

Generally, basic problems can be fixed by clip-on ferrites which are available from Jaycar, RS Components and element14. The longer the ferrite, the better the effect, along with volume, ie, the larger the better. The ferrite is simply clipped over a lead near the product, usually mains power, and if possible a second loop will improve the effect. Other leads from a product may also be a noise source so a little experimentation will reveal the problem area.

Lastly, a give-away: as an engineer for over 40 years, I have accumulated a large electronics library which includes microprocessor design, analog

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Mailbag: continued

Vintage TV is unwanted & unlamented

During a recent trip to the shops, I spotted an old TV on the kerb awaiting council pick up. Now I understand this is not something new these days; in fact, I often see these as a good source of parts, particularly flyback transformers and other non-aging components if needed for a current project. However, this is a genuine vintage television with hot bottles (I think they were called valves in their day).

I have seen vintage televisions before but they are nearly always brutally ratted by the scrap vultures for copper. I do check them nonetheless to salvage any undamaged hot bottles to add to my collection of unusual and historic electrical items.

So I now have this heavy television and would like to know if there is a serious restorer or collector amongst your readership who would be interested in having this piece of Australian history to add to their collection. From what I can tell, it is complete other than the legs and the centre knob for the fine tuning of the channel selector, but it does need some cleaning up.

I am happy to crate it up and arrange dispatch from my end if the transport charges are covered by the recipient. I am in Western Australia.

Mark G,
via email.

Comment: unfortunately, there seems to be very little interest in vintage TV. The main problem appears to be that TVs are far more bulky and much heavier than radios. More to the point, TV circuitry is far more complex and more difficult to understand than a typical 5-valve superhet radio. Finally, if a picture tube has failed or is on its last legs, there is very little chance of finding a replacement. The same comment probably also applies to components like yokes and flyback transformers.

design, logic design, basic engineering, control systems and digital audio. I would like to offer a number of these texts, free, to any readers who would like to have them for their own library. I would be happy to arrange pick-up from my home – contact **bbloom@emi-solutions.net.au**

Congratulations on your excellent magazine.

Braham Bloom,
Russell Lea, NSW.

Questions about costs of hybrid solar system

I would like to begin by saying "I dips me lid", to Geoff Woodman. His Hybrid Solar System is a very sound design, based on the currently available materials and acceptable installation practices.

My concern is that the article in the October 2015 issue has some credibility flaws that culminate in an artificial cost analysis, which could lead the uninitiated to a very romantic notion of the real cost of such a system. My agenda is not to denigrate either the system designer or the journalism but to encourage more of such enterprising efforts, in the clear understanding that eventually this type of system will be common. Entrepreneurs like Geoff are pioneers. Their efforts can demonstrate both the shortcomings and the benefits of a practical installation.

I have used eBay costings to "re-jig" a realistic cost analysis, not to be overly critical but because accurate costings can lead to designs that bring the affordability of hybrid systems closer to practical realisation.

On eBay today, Geoff's batteries were $1553 each, making his set $37,272. From the same source, his 54 300W cells were $550 each, coming to $29,700. Just for simplicity, I will allocate $10,000 for the rest of the installation, although this would likely be more if the system was not owned by a licenced tradesman. Therefore the total cost would be $66,982.

But battery costs are only superficially a capital cost. I prefer to treat the storage costs as consumables which, until flow cells arrive, is simply being realistic.

What took my eye when reading the article is the statement that the Sonnenschein cells had a lifetime of 4500 cycles at 65% SOC. Referring to the published data, the A600 cell can achieve 3000 cycles at 20% DOD, which is actually only 80% SOC. At 65% SOC, equivalent to 35% DOD, the published maximum number of cycles is 1700.

The cycle life is rather less than the service life (20 years) due to unexpected influences. [Gel-Handbook, Part2 (Edition 17, January 2012) Industrial Power, Application Engineering].

If the stated working parameters are accurate then the installation will enjoy 4.6 years of effective operation. From my experience, a practical installation will start to deteriorate noticeably some time sooner than this because controllers react to system conditions, occasionally adding cycles into the daily expected cycle.

All things being equal, Geoff Woodman will notice his supplementary grid supplied costs are escalating after five years. Therefore, calculations of pay-back periods must treat the functional battery life for storage as a cyclical cost. If Geoff adds $37,272 to the running costs at approximately five to six years, the payback period jumps disturbingly.

Jack Ryan,
Redland Bay, Qld.

Large hybrid solar systems are not economic

I refer to your article on page 22 of the October 2015 issue: "A Large, Real-World Hybrid Solar System".

It is an interesting article from an engineering perspective but it doesn't address one key topic: what was the main purpose of going to all this expense and effort? Was Geoff Woodman intrigued by the engineering challenge of designing and building such a system or does his business depend on a no-break power system, or did he think he would save on his energy costs, or does he think he is doing his bit to save the planet?

Your article does have a short paragraph titled "Investment & Return" which purports to demonstrate (see note 1 below) that the system would pay for itself within eight years, so my guess is that Geoff believes that he is going to reduce his overall energy bill

and thus save some money. However, I would like to challenge that view.

I would assert that to determine if a complex installation like this is economically a benefit, then a number of factors need to be considered. For example, the 24 storage batteries cost $50,000 and although your article makes no mention of this, I would assume that they would have to be replaced in about 12-15 years, so you have the disposal and replacement costs of the battery pack.

Similarly, the solar panels have a useful life of 15-20 years, during which time their output diminishes. When they reach their end-of-life, they too have to be removed and carefully recycled, at some significant expense. And there is the ongoing maintenance of the whole system; cleaning the solar panels regularly (could be three or four times a year), repairs and replacement of the inverters and other electronics. And finally, there is the "opportunity cost" of the $70,000 that Geoff has tipped into this project.

Let's assume that this system is only designed to be used until the batteries need replacing in, say (and I am being very optimistic), 15 years time, at which time the system will be decommissioned and all the components recycled.

Let's also assume that the maintenance costs are $1000 per annum and that the cost to recycle all the components is $5000. From that, the total lifecycle cost (to Geoff) of this system is actually $90,000 ($70,000 + 15 x $1,000 + $5000) which does not include the $10,000 that the tax-payer tipped in at the start through the RECs. If the initial $70,000 had been invested for the 15 years and assuming a simple rate of return of 5% after tax on that investment, then the "opportunity cost" is another $52,500.

The total cost of this project over a 15 year life is therefore $142,500. That equates to $9500 per year over 15 years, which is way more than the $5000 per year that he has saved on his energy bills! That doesn't look like a viable economic proposition to me.

Looking at it even more critically, you say that Geoff saved $5000 on his annual electricity bill and then go onto to call that a "yield" of 7% and then further inflate it to 12% "before tax". However, this is incorrect as the original amount of $70,000 has been spent and cannot be recovered at the end of the investment period so it cannot be compared to a normal investment. The payback period is not about eight years, as you have not included the "opportunity cost" of the $70,000. Taking into account the opportunity cost (at 5%) and the maintenance costs, then the payback period is closer to 140 years!

Alternatively, another way to assess the economics of this project is to consider if you had $70,000 to put towards energy (electricity) costs over the next 15 years:

(a) You could invest the $70k at 5% after tax and use the earnings and part of the principle to pay the annual power bill of $5000. After 15 years, you would still have $37,632 left.

(b) Or you could use the $70k to build a hybrid solar system like Geoff's. After 15 years, you would have saved

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Mailbag: continued

Solar-powered cars good for commuters

That was an excellent article by Ross Tester in the October 2015 issue, about the Immortus solar powered car. It's about time that the electric car came into its own. The technology now exists to create a car that runs exclusively on solar. For some reason, car manufacturers today seem to still believe that making cars that weigh tons is necessary! The majority of its motive power is used to just get the thing moving!

The Immortus proves that a car can be made out of space-age materials and can be light and constructed in a way that it can be disassembled completely and easily for recycling. With car manufacturers pulling out of Australia, that leaves a hole that can be filled by aspiring entrepreneurs who can take this technology further and manufacture an electric car for general commuting.

It has been proven that 80% of our driving is to and from work and a range not exceeding 80km. It's time for Australia's ingenuity to take root again and to prove itself on the world stage. Any takers?

Greg Johnson,
Numeralla, NSW.

Comment: one reason that today's cars are so heavy is crash protection. The Immortus has virtually none.

$75,000 (15 x $5000) in electricity bills, have spent another $20,000 on maintenance and recycling costs and have nothing left of the initial $70,000. So, you would have spent $90,000 to save $75,000 – which doesn't look like an attractive investment to me . . . as you are $52,632 worse off than option (a).

A similar error in estimation of the payback period occurs in the letter by Dr Alan Wilson in the Mailbag pages of the October 2015 issue.

Unfortunately, that item contains a couple of significant errors and thus gives a very optimistic pay-back period and rate of return. Alan has not taken into account the "opportunity cost" of the $15,000 that the solar installation cost and he has assumed that this is like any normal investment in calculating a return of 11.45%.

Let's assume that the solar system that he installed for a total cost of $15,000 has a useful life of (optimistically) 20 years and that the electricity it generates saves $1717.00 per year for each of those 20 years. Let's also assume that the maintenance costs (cleaning of the panels, repairs/replacements to the inverters) averages $100 per year and the cost to dismantle the panels and responsibly dispose of them at the end of the 20 years is $1000.

The calculation of the payback period must take into account that the $15,000 could have been earning a return if it had not been spent on the solar panels. Let's assume that it could have been earning 5% compound after tax. After 20 years, this account would have a balance of $37,904.

The solar panels after 20 years, however, would have only saved a total of $31,340 after maintenance and disposal costs are taken into account. So you can see that the pay-back period is somewhat greater than 20 years and the panels have already reached the end of their useful life. Thus, the solar panel system never achieves a pay-back period during its useful life.

The calculation of a rate of return needs to account for the fact that the initial principal (the $15,000) is not preserved and is not returned at the end of the investment period; similarly for the ongoing maintenance costs and the disposal costs. Using the above assumptions, the total amount tipped into the solar installation is $18,000 over the 20 years, the total gross return (@ $1717 pa) is $34,340 and the net return is $16,340.

Thus, the real rate of return is just 4.5% per annum.

As you can see, putting a solar panel array on your roof to save money does not make economic sense. You are better off investing the money and using the investment proceeds to pay your electricity bills.

Dennis Malseed,
Balwyn North, Vic. SC

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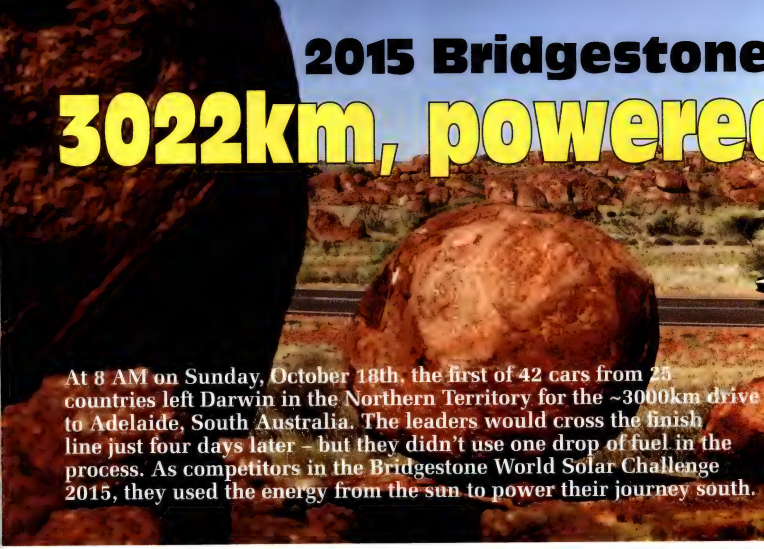


2015 Bridgestone
3022km, powered

At 8 AM on Sunday, October 18th, the first of 42 cars from 25 countries left Darwin in the Northern Territory for the ~3000km drive to Adelaide, South Australia. The leaders would cross the finish line just four days later – but they didn't use one drop of fuel in the process. As competitors in the Bridgestone World Solar Challenge 2015, they used the energy from the sun to power their journey south.

The Bridgestone World Solar Challenge is much more than *just* a 3000km race for solar-powered vehicles.

Sure, winning the race itself is the ultimate prize but simply getting the car to the start line is arguably 90% of the effort (and cost). This is simply because every team has spent thousands of man-hours in designing, building, testing, rebuilding, retesting and fine-tuning their entry, long before they get it anywhere near the "track" – in this case, the entire length of the Stuart Highway, in sometimes 40°+ heat and Red Centre dust!

Every car (and that's a term that's arguable!) is different, reflecting the team's philosophy and budget. Most teams are drawn from universities and colleges, where the World Solar Challenge entry brings together several faculties in a spirit of cooperation:

- **Electronic and electrical engineering**, of course, for virtually all cars have quite comprehensive (and unique) computerised control and management systems which not only determine how the energy is derived and used but reporting back in real time to their support vehicles.

Virtually all competitors had quite sophisticated radio links back to their support vehicles which not only relayed telemetry to the support crew but allowed two-way

How about some more technical details?

We'd love to bring you some of the more specialised technical information on the cars in the 2015 World Solar Challenge . . . but this information was difficult, if not impossible, to obtain,

It seems the entrants were all playing their cards *VERY* close to their collective chests, mindful that any information they might supply could be used by their opposition when they return for the 2017 World Solar Challenge.

Yes, most teams will be back – the comments on social media were particularly enthusiastic, not just about the organisation and conduct of the race itself but also the camaraderie and co-operation between teams, the social aspects (*especially* the social aspects, after all we are talking about university students in the main!) and, not the least, the stunning Aussie outback scenery and weather.

One commented that he would never have believed there were so many stars in the sky if he hadn't seen them himself. Another waxed lyrical about the amazing sunrises and sunsets in the outback.

As a spectacle, apart from the start and finish the Bridgestone World Solar Challenge doesn't offer too much: 46 teams spread across thousands of kilometres of outback road, going past at maximum possible speed.

But for those who competed, and for all those overseas following the race via the net, it is one of the most fantastic advertisements for Australia you could hope for!

World Solar Challege: by sunlight

BRIDGESTONE WORLDSOLAR CHALLENGE

by ROSS TESTER

Stella Lux, the energy-positive family solar car from Dutch Solar Team Eindhoven drives through Devils Marbles Conservation Reserve on day two of the 2015 Bridgestone World Solar Challenge. Photo: TU Eindhoven, Bart van Overbeeke

communication between support crew and driver. "*Road Train Approaching*" was enough to put the drivers' collective hearts in their mouths!

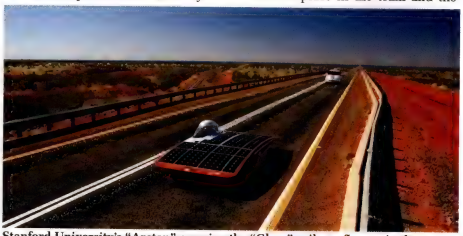
- **Computer sciences:** some teams use off-the-shelf equipment from their sponsors, tailored to suit the exacting requirements of the challenge. But just as many design and build their computer equipment, then write the software required for their car.

The top crews had every aspect of car operation – and even the driver's state of health – monitored at all times.

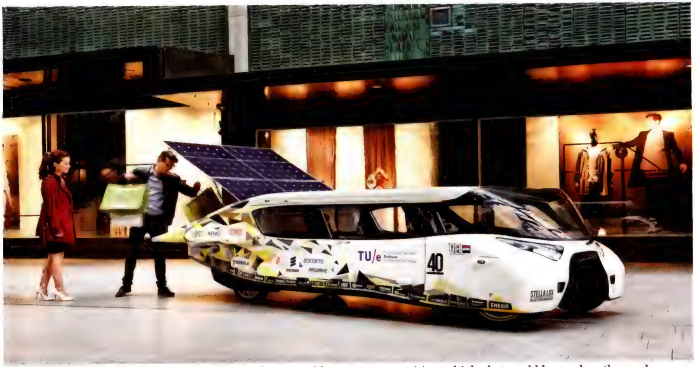
- **Mechanical engineering,** which is largely responsible for the design and building of the vehicle itself. Some have access to wind tunnels; others have to rely on the theory that they have been taught. In all cases, students were responsible for building and refining their designs to come up with "the" racer which could be the Challenge winner.
- **Business studies**, responsible for raising the rather significant funds required for a serious attempt on the World Solar Challenge. While in most cases they can rely on some support from their own school, all are most reliant on sometimes millions of dollars worth of sponsorship.

One leading team had no less than 113 sponsors listed, mostly related to some aspect of the attempt. Some sponsorship is in kind, where state-of-the-art equipment (eg, solar panels) is supplied either free or at a substantial discount.

- **And finally, the students themselves** – in virtually every case, they had to raise the funds to get them a place in the team and the



Stanford University's "Arctan" crossing the "Ghan" railway flyover in the Northern Territory desert, followed by their chase vehicle. We are assured they had nothing to do with the bent guard rail!



The "Cruiser Class" aimed to replicate, as much as possible, a race-competitive vehicle that could be used on the road and rely solely on solar power. This publicity shot, from the Dutch Solar Team Eindhoven and their four-seat "Stella Lux" demonstrates just that. The Stella Lux was no slouch in the race, coming second in the class, 13 minutes behind the winners.

"working holiday" to Australia.

For many students coming from Northern Europe or Northern America, the central Australian climate, even in October, was something of a shock to the system.

Classes

There were three classes in the race: Challenger class, which had highly aerodynamic single-seat cars built for speed and range, not for comfort (the type of solar racers you're probably used to seeing); Cruiser class, where cars were built for practicality – as closely as they could mimicking your typical passenger cars with up to four seats; and finally Adventure Class, not quite a "beginner's" class but one which allows teams to enter which may not have the (sometimes huge) financial backing of the other classes and in some cases do not comply with the technical requirements of the other classes (though they must meet all safety requirements).

There was a further class allowed for

Is it sunrise . . . or sunset? Regardless, teams oriented their vehicle's solar panels (in most cases taking them right off) to catch the absolute maximum sunlight possible to charge batteries before the 8 AM start deadline or after the 5PM finish deadline, ready for next day. Here the "Stella Lux" team manoeuvre the solar panels into the best possible position.

Where the Challenger class was built for speed, the Cruiser class also added comfort and convenience, even to the large LCD screen. Photos above and opposite: TU Eindhoven, Bart van Overbeeke

under the rules, the Evolution class, which had less restrictions placed upon, for example, energy sources and capacities but this year there were no entrants in that class.

Challenger class

This class is arguably the toughest to enter because the competition is so intense. Each vehicle is designed for sustained endurance and total energy efficiency.

The overall winners of the 2015 World Solar Challenge came from the Challenger class, if only because they were the fastest on the road. (Actually, the rules stipulate that the Challenger class winner will be declared the overall World Solar Challenge winner).

Unlike the other classes, which have a compulsory overnight stop in Alice Springs (where they can recharge from the grid if necessary – and usually do!) the Challenger class is a "one stage" event, travelling direct from Darwin to Adelaide.

The vehicles rely on their solar

TAFE SA's "Solar Spirit" competed in the Adventure Class. This car has actually been in existence since 2010 and competed in the 2011 and 2013 challenges. There are no "big dollars" behind the team; it used off-the-shelf componentry and ingenuity instead!

While the World Solar Challenge offers a very useful test bed for IBM's forecasting technology, it could have much wider implications. The winning Dutch teams had similar technology, courtesy of Philips.

panel installation to both power the drive motors and to charge the (limited) on-board batteries, which help keep the vehicle moving during cloudy periods or under shade.

No vehicle is allowed to compete at night.

Driving is as carefully managed as power: it's a race, but if the vehicle is driven too fast extra energy is used and the batteries will be depleted.

This year, Challenger class vehicles are slightly shorter than in previous years at just 4.5m maximum. They also have a maximum width of 1.8m. Into this must be packed a solar array of $6m^2$ maximum (or just $3m^2$ maximum if using GaAs cells).

Similarly, there is a limit to the mass of on-board batteries allowed – with Li-ion and Li-polymer they can carry up to 20kg, $LiFePO_4$ 40kg, NiMH 70kg and lead-acid 125kg. We don't believe any vehicle carried the heavier batteries.

There is only room for one driver, who must have a minimum weight of 80kg (or carry ballast to meet this minimum). Up to four drivers are permitted, each with that same 80kg minimum/ballast and each must have had at least 12 hours of logged driving in their team's solar vehicle. All drivers must be licensed in their home countries.

The vehicles may not start to race before 8 AM and must be "parked", almost always on the side of the road, by 5 PM.

Every team has a lead and chase vehicle, with one seat given to an official race observer who ensured that competitors play be the rules. For example, every minute on the road before 8 AM or after 5 PM will be penalised 10 minutes in overall time.

They were also looking for bad or unsportsmanlike driving, eg, deliberately holding up a team trying to overtake.

Unlike some vehicles in other classes, Challenger solar cars must have four wheels. There are new requirements in the 2015 race for improved driver vision in all directions – some use conventional mirrors for rear view, others rely on electronic systems (or both).

Managing . . . everything!

Extreme importance is given to solar energy management and engine management. The rules are quite specific on how this is to be done, with extensive and compulsory documentation required.

Another important part of the rules is driver safety – each vehicle must have emergency power disconnection accessible from both inside and outside the vehicle and every team must have a safety officer and a battery officer who are responsible for ensuring driver, team, other road users and public safety.

The rules and regulations for the race are detailed in a 44-page manual. Every aspect of vehicle construction and its fittings are covered; for example solar cells, batteries, brakes, steering (even the type of steering wheel), seatbelts, tyres, wheels and so on.

Every vehicle competing in the race must present a roadworthiness certificate from their home country but also undergo extensive mechanical, electrical, construction and safety scrutineering before the race starts. Vehicles failing this scrutineering are not allowed to compete.

Cruiser Class

Cruiser class "aims to change the way we think about what we drive and what fuels we use".

The Coates Hire Car Tracker gave vehicle positions, courtesy of their GPS systems, theoretically in real time. The inset shows the first five cars to finish in Adelaide – Nuna8 (No.3, parked in King William St), took the honours.

The class was established in the 2013 race, in which one four-seater "family" car travelled the 3000km race route using just 64kWh of external energy (ie, electricity) input.

If this doesn't excite you, a very efficient modern petrol car travelling the same route would use an energy equivalent of around 5000kWh!

Cruiser class vehicles are designed for practicality and as well as being judged on this will also earn points for the time taken to traverse the course, external energy use (or more particularly lack of it) and payload carried.

These vehicles are, to some extent, seen as the fore-runners of the electric vehicles which we will all be driving tomorrow.

Most of the requirements of the Challenger class must also be met by Cruiser class vehicles. As mentioned earlier, one big exception for the Cruisers is that it's a race of two halves – Darwin to Alice Springs and Alice Springs to Adelaide.

During the compulsory night stop in Alice Springs (close to the half way point) Cruiser class vehicles can be recharged from the grid.

Triple the battery capacity is allowed under Cruiser class than Challenger class; 60kg for Li-ion or Li-polymer and 120kg of $LiFePO_4$. Cells may not be removed unless in a hazardous situation but packs can be removed (eg, at night) but must be locked away under direct supervision of the team observer.

No grid recharging is allowed except for the designated night stop above.

Adventure class

There were only three entrants in the Adventure Class, and one of those didn't quite make the distance!

Both finishing teams came from the US: The Liberty Solar Car team's car, the Solis Bellator, came from the Liberty Christian School from Argyle, Texas, while the Houston Sundancer was entered by students from the Houston School of Science and Technology.

These teams, while highly skilled and professional in their own right, do not have the immense backing of many other teams (ie, the Challenger and Cruiser classes) and in many ways is seen as a "stepping stone" to get into the top classes in future events.

While the winners were celebrating with an impromptu dip in Adelaide's

The Philosophy behind the Development of the Classes

By Chris Selwood, Event Director

Primarily a design competition to find the world's most efficient electric car, the biennial World Solar Challenge seeks to inspire some of the brightest young people on the planet address the imperatives of sustainable transport.

The original and largest event of its type, it maintains its position by offering an adventure of epic proportions: crossing a continent in a single stage using only sunlight as fuel.

Every two years, teams from around the globe work tirelessly to design and build an ultra-efficient electric vehicle, bring it to Australia and, in the spirit of friendly competition, prove their concepts in one of the world's harshest environments; the Central Australian Desert.

The philosophy of evolving design parameters and creating regulations around what must be achieved, without dictating how they are to be achieved, not only encourages creativity and lateral thinking but provides a unique opportunity of engaging with some of the issues which face us all and a philosophy which has led this famous international event to its position of global dominance.

This openness has fostered the innovative strength of thought that continues to come to the fore as teams look to create the ultimate efficiencies in energy capture, storage and conversion. The World Solar Challenge may have the sun as its nucleus but its innovation reaches into many other areas such as advanced composite materials, low rolling-resistance tyres and innovative power-electronics capable of ultrafast switching of the high current inductive loads demanded by modern EV powertrains.

When first devised, the solutions were only limited by the imagination, although practical considerations were soon to drive the regulations. If solar cars were to drive on public roads, they should be of an appropriate size. If the cars were truly solar powered, there should (for the purposes of a competition) be a limit on the stored energy they brought with them.

So, based on the admittedly somewhat fanciful notion that we, as humans, each have 8 square metres of the earth's surface from which to draw our sustenance, solar collectors (not defined by type) were originally limited to 8 square metres, however with more efficient conversion leading to faster cars, this was dropped to 6 square metres in 2009 and, in 2011, space grade technologies such as Gallium Arsnide were limited to 3 square metres.

Energy storage limits, again for the sole purpose of competition, "retained to this day" a relationship to the power required to complete the course and, as far as we are aware, the World Solar Challenge is the only event which does this. Based on a reference point that if a one kilowatt car could complete the course in 50 hours, we consider it reasonable to allow 10% of the energy requirement to be stored to assist with hills, clouds, or extra acceleration for overtaking. Thus a nominal figure of 5kW was, and remains, the original determinant of the allowable mass of batteries, and the basis of the current calculation by class.

Rapid advancements in technology coupled with a growing acceptance of the imperatives of environmental action require constant review and evolution of the design parameters required to keep the Challenge both attractive and relevant. Experienced teams need to be pushed in order for innovation to flourish, but at the same time the tasks should not be seen as impossible by newcomers.

Motivators also change with time. At one end of the scale we have young people inspired to attend by what they read and saw as children, and seek the adventure. At the other, the brightest students take a two-year sabbatical to immerse themselves in the project thus gaining wide ranging experience beyond campus life.

The world is also changing. In early events there were few reference points for home made vehicles or regulations for electric cars. This led to to the development of road protocols and safety regimes specific to the event. That these were adopted by other events proved their efficacy.

Now the developed world recognises myriad regulations for "individually constructed vehicles" harmonised by the UNECE. The Institute of Electrical Engineers has set wiring standards of electric vehicles, and transport authorities around the world are reacting to the rapid developments in urban mobility and the technology which drives it.

The World Solar Challenge: *Adventure. Innovation. Achievement.*

Another shot of the crews, this time from Michigan University's "Aurum", working hard to get the last photon of sunlight into the solar cells. The two guys with spray bottles of water employ the only method of solar cell cooling allowed.

Victoria Square Fountain, the two Adventure class vehicles had not long crossed from the Northern Territory into South Australia.

Active forecasting

When seconds count, the teams grab any possible advantage that's within the rules. As you would realise, the solar cells work at maximum efficiency in bright sunlight – any shading can drop the output significantly. And that includes shading from clouds.

At least two teams, the Aurum (University of Michigan) and the Stella Lux (Solar Team Eindhoven) featured advanced solar forecasting capabilities through deals with their sponsors – IBM, in the case of UM and Philips, for Stella Lux.

Both teams were able to obtain instant weather information while travelling, which was combined with historical data for the route.

Armed with this, they were able to pass information through to the driver on, for example, any cloud build-up, its direction and speed, so the driver could either try to outrun the clouds or slow down and let the clouds pass.

Follow those cars. . . maybe

Coates Hire sponsored what was supposed to be a real-time display of all entrants which could be called up on line.

It nearly worked . . . except for the times when the GPS data (and therefore the location) was hopelessly out of date (up to 12+ hours out) and, in some cases, simply wrong because of a glitch. For example, at the end of race time (5 PM) on the second-last day, the map showed the leaders in Port Augusta, SA . . . whereas at the start of the last day (8 AM) they had just 177km to go. Hmmm.

But we're assured the positions shown at the finish are correct – and there are plenty of photos to prove it.

And the winners were:

The 2013 winners, Nuna7 from the Nuon Solar Team of Delft University in the Netherlands, returned with an even better car, the Nuna8, to defend their world title. And defend it they did, taking out the Bridgestone World Solar Challenge in a time of 37:56:12.

Even on day 1 of the race, the pace was on. But it took until the fourth day for Nuna8 to take the lead, then hold off their main rivals, another entry from the Netherlands, to claim their sixth victory in the race!

Second place was the Delft University's Solar Team Twente's "Red One" which pushed Nuna8 all the way, never more than a few kilometres behind. Its official time was 38:04:32.

Winners are grinners . . . and wet! Here the support team for the Nuna8 is lifting the the solar panel "lid" off the car once they had passed the "ceremonial" finish line. Actual timed finish was outside Adelaide to ensure traffic congestion wouldn't influence the official positions but cars still had to make it to the Victoria Square finish line. At right, Nuna8 team members take a ceremonial "paddle" in the Victoria Square fountain.

Winners of the Cruiser Class in the World Solar Challenge, the "Owl" from Japan's Kogakuin University.

Third place went to the Tokai University (Japan) entry, the "Tokai Challenger" at 38:50:07.

In the Cruiser class, it was a race in two: Kogakuin University's "Owl" (48:07.00) and another Dutch team, the Solar Team Eindhoven in their four-seater "Stella Lux" (48:54:59). Incidentally, the Stella Lux earned pole position at the start of the race by taking out the time trial at the Hidden Valley racetrack but the Owl crossed the finish line nearly an hour ahead of Stella Lux in Adelaide.

During the race, Stella Lux achieved the remarkable feat of travelling 1500km on a single battery charge!

Australian competitors

Considering the enormous amount of support – dollars and otherwise – that many of the overseas teams enjoy, Australian competitors didn't fare too badly.

In the Challenger class, Clenergy TeamArrow and their Arrow1-GT were in eighth place (45:22:00), two ahead of the Western Sydney University's "Unlimited" (46:51:00). The Adelaide University's "Lumen" was further back again (55:42:00) but travelled 35% of the race on their trailer.

Even better results were achieved in the Cruiser class, with the UNSW-Sunswift "eVe" coming in third in 55:28:44.

Trailering

Only five of the Cruiser Class managed to complete the course without requiring assistance in meeting stage deadlines. All bar seven of the Challenger class managed to compete under their own power.

Usually this assistance – "trailering" – was required because of equipment failures or other "on the road" problems (including, for example, running out of power).

All teams were required to have a trailer for this purpose. Some of those "trailers" were more like mobile workshops.

When they didn't meet the stage deadline, cars were given a lift to the next control point ready for next day's competition. Naturally, trailering cost the team significant points in the overall competition using a distance-based formula.

One team, the Durham University's "DUSC2015" (UK) actually recorded a negative distance under solar power against 1495 kilometres of "trailering" when they reached Alice Springs! Surprise . . . they were coming last! Well, maybe not quite last: Siam Tech1's STC1 (Thailand) was withdrawn from the race and India's RVCE "Soleblaze" didn't even make the start line.

The popular "tunnel" design, for aerodynamic stability, is demonstrated in this front-on shot of the second-place getter in the Cruiser class, Stella Lux.

The University of Michigan's huge "Car Trailer" – capable of not only holding the car but was also a mobile workshop with all equipment the team could ever possibly use . . . and let's not forget those vitally important sponsors!

Well, a few things we *have* learned about Solar Challenge cars . . .

Earlier we mentioned that it proved rather difficult to find any information on what equipment the cars were using... apart from general information, such as the winning Nuna8 sported 391 monocrystalline silicon cells offering an impressive 24% efficiency; that the body was a carbon fabric/foam sandwich, similar to that used in formula 1 cars; that it had 96% efficient Mitsuba engines integrated into the rear wheel rim and that it was aerodynamically shaped to improve road-holding and stablitity.

We also found more details on the 2013 winner, Nuna7 (on which Nuna8 was closely based). [See below]

That was about the limit of data, until we found the photograph at right of an unidentified 2015 Bridgestone World Solar Challenge car's control equipment.

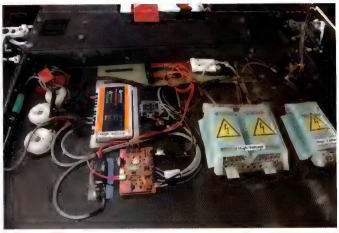
Together with a magnifying glass, we were able to identify at least some of the componentry used and make some educated guesses on what we think was the make-up.

For example, the fact that there are three blue boxes on the right side of the picture and three inductors on the left automatically suggests that the motors being used were three phase – just as we would have expected.

We know (from previous races) that the majority of these were "pancake" type motors which pack an enormous amount of grunt for their size.

We also know that the motors are extremely efficient – the (albeit limited) spec sheet for the Stella Lux, for example, claims a high 97% efficiency.

Efficiency is absolutely vital when you're running the motors from a supply limited by what you can generate from the sun (in many cases, it was reported that onboard batteries were exhausted or near exhausted during the day – the cars were running on what the sun provided).



Nuna7 (2013 Winner) Specifications

Dimensions	4.5 x 1.8 x 1.12m (l x w x h)
Weight	180kg
Driver	Weight supplemented to 80 kg
Wheels	4
Solar Cells	392
Motor	InWheel Direct Drive Electric Engine Integrated motor in rear wheel
Efficiency	98%
Battery	21kg Lithium Ion cells
Capacity	5.3kWh
Body	carbon fibre and foam sandwich construction Aramid reinforced parts Titanium roll bar
Aerodynamics	Specially designed wing profile Revolutionary asymmetrical design Tested and proven in the windtunnel
Suspension	Aluminium uprights, hold by aluminium leading arm below with single A-arms of carbon fiber Integrated dampeners in suspension Lightweight magnesium rims High precision ceramic bearings Titanium axles
Tyres	Low resistance profile tyres specially developed with Michelin for solar racing
Brakes	Regenerative braking with the electric motor
Rolling Resistance	> 10 times less than a conventional vehicle
Air Resistance	> 11 times less than a conventional vehicle
Telemetry	Wireless connection with support vehicle Support vehicle determines the speed of Nuna using touch screen application

WaveSculptor 22 Inverter

But one of the more interesting components we identified is that large-ish orange and black box in the middle of the picture. It's a Wave-Sculptor 22 Motor Inverter, one of a range of products from Brisbane-based Tritium Pty Ltd (www.tritium.com.au).

A quick check of their website showed that this was indeed the inverter of choice, claimed to be "used by nearly all leading solar racing car teams worldwide . . . ".

According to the manufacturers, the WaveSculptor 22 is one of a family of inverters. This one is a high-efficiency, low weight, 3-phase 14kW variable frequency inverter especially designed to drive high-efficiency, low-inductance, permanent magnet motors

The suite of firmware, software and ancillary products that form the WaveSculptor drive system work together to make the motor controller easy to configure and compatible with a wide range of electric motors.

The WaveSculptor 22 is not cheap at $AU6000 plus GST. However, given the number of Solar Challenge teams investing in one of these Australian-made and produced products, it seems that they all believe they represent good value for money.

Each WaveSculptor 22 is supplied with a motor position/temperature adaptor, a CAN-Ethernet bridge, power adaptor and a 1m CAN cable.

For more information on the Tritium WaveSculptor range, contact Tritium Pty Ltd, 16 Cavendish Rd, Cooparoo, Qld 4151. Tel (07) 3129 4389; email enquiries@tritium.com.au

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WaveSculptor 22 Motor Inverter Specifications

Peak Power Rating:	20kVA
Average Power Rating:	up to 20kVA with water cooling
Motor type:	3-phase permanent magnet (BLDC) or induction
Cruise Efficiency:	99.2%
Cooling Method:	cold plate
Maximum Battery Voltage:	160VDC
Maximum Motor Current:	100A rms
Drive Waveform:	Sinusoidal
Communications:	CAN bus
Size:	255 x 165 x 35mm
Mass:	855g

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NOTE: PCBs from past ~12 months projects only shown here but the SILICON CHIP ONLINESHOP has boards going back to 2001 and beyond. For a complete list of available PCBs, back issues, etc, go to *siliconchip.com.au/shop* Prices are PCBs only, NOT COMPLETE KITS!

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Price for any of these micros is just $15.00 each + $10 p&p per order#

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Some micros from copyrighted and/or contributed projects may not be available.

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PIC18F14K50	USB MIDIMate (Oct11)
PIC18F27J53-I/SP	USB Data Logger (Dec10-Feb11)
PIC18LF14K22	Digital Spirit Level (Aug11), G-Force Meter (Nov11)
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When ordering, be sure to nominate BOTH the micro required AND the project for which it must be programmed.

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MINI USB SWITCHMODE REGULATOR Mk II all SMD components *(Sept15)* **$15.00**

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includes precision resistor. Specify either 1.8V or 2.5V

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The Largest Astro
Of All Time . . . 46

A tiny section of the Milky Way showing Eta Carinae; itself a tiny section of the 46-billion pixel image shown at top of page.

nomical Image BILLION Pixels!

by Ross Tester

Astronomers at the Ruhr-Universität Bochum in Germany have compiled the largest astronomical image to date – a picture of the Milky Way which contains 46 billion pixels. The image contains data gathered in astronomical observations over a period of five years.

Called the **Bochum Galactic Disk Survey**, they monitored a 6° wide stripe along the southern Galactic disc simultaneously in the r and i bands, using a robotic 15-cm twin telescope of the Universitätsternwarte Bochum near Cerro Armazones in Chile. Utilising the telescope's 2.7° field of view, the survey observed a mosaic of 268 fields once per month and monitored dedicated fields once per night. The survey reached a sensitivity from 10m down to 18m (AB system), with a completeness limit of r ~ 15.5m and i ~ 14.5m which – due to the instrumental pixel size of 2. 4" – refers to stars separated by >3".

Five-year observation period at the observatory

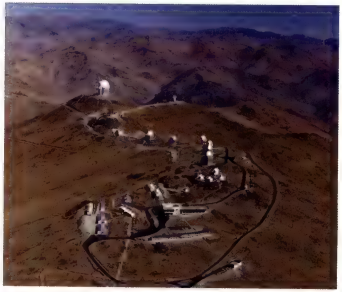
For five years, the astronomers from Bochum have been monitoring our Galaxy in the search of objects with variable brightness. Those objects may, for example, include stars in front of which a planet is passing, or multiple systems where stars orbit each other and which obscure each other every now and then.

In his PhD thesis, Moritz Hackstein is compiling a catalog of such variable objects of medium brightness. For this purpose, the team from the Chair of Astrophysics takes pictures of the southern sky night after night, using the telescopes at Bochum University's observatory in the Atacama Desert, Chile.

More than 50,000 new variable objects, which had hitherto not been recorded in databanks, have been discovered by the researchers so far.

268 individual images make up the photo of the Milky Way

The area that the astronomers observe is so large that they have to subdivide it into 268 sections. They photograph each section in intervals of several days. By comparing the images, they are able to identify the variable objects. The team has assembled the individual images of the 268 sections into one comprehensive image. Following a calculation period of several weeks, they created a 194 Gigabyte file, into which images taken with different filters have been entered.



Bochum University's Chilean Observatory is one of those located at La Silla in the Atacama Desert, one of the driest and most inhospitable places on Earth. The photo at the top of the page (and the extract of a miniscule portion of it at left) were the result of five years of photography of the Milky Way galaxy, with the 286 individual images "stitched" together to form the 194GB file.

Online tool facilitates search for individual celestial objects

In order to view it online, researchers headed by Prof Dr Rolf Chini from the Chair of Astrophysics have provided an online tool (http://gds.astro.rub.de/). Using this, any interested person can view the complete ribbon of the Milky Way at a glance, or zoom in and inspect specific areas.

An input window, which provides the position of the displayed image section, can be used to search for specific objects.

If the user types in "Eta Carinae", for example, the tool moves to the respective star; the search term "M8" leads to the lagoon nebula. SC

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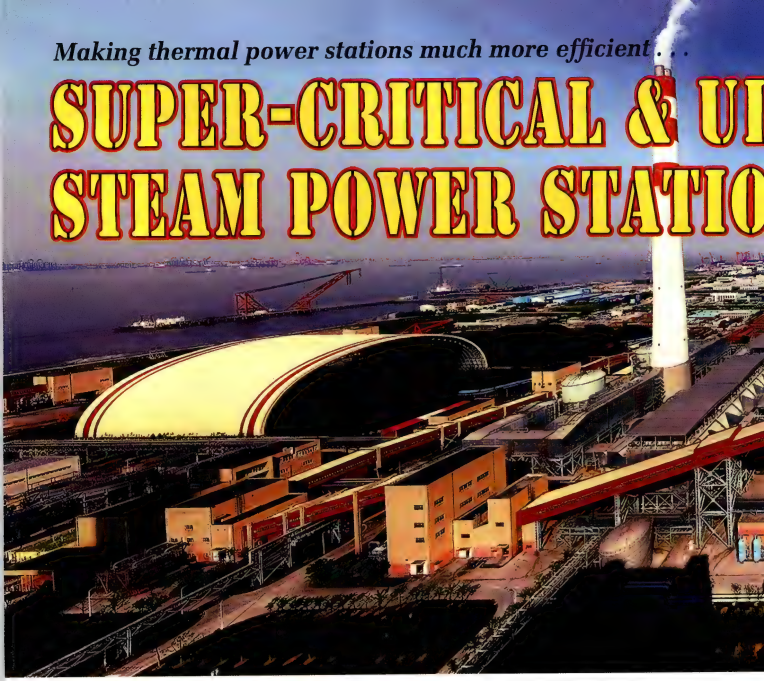
SUPER-CRITICAL & UL
STEAM POWER STATIO



Coal-fired power stations are out of favour in much of the Western world because of carbon dioxide emissions but there is a way in which they can be made more efficient, ie, to use less coal and emit less CO_2. This article is mainly about super-critical and ultra-supercritical steam power stations but does include other technical improvements to thermal power stations.

While there is much emphasis on "green" or renewable power sources, they are much more expensive than conventional sources such as coal-fired or nuclear power stations which are the only practical and economic way to provide base load power (the minimum amount of power drawn through the power grid 24 hours a day), unless a country has enormous dams and the accompanying huge hydroelectric power stations.

Intermittent sources of power such as solar or wind must be backed up at all times by either fossil fuel, nuclear or hydroelectric plants to whatever the capacity is of the solar or wind plants, as at any time the wind might stop blowing or clouds might cover the sun and the loss of power must be rapidly made up. This causes conventional base load plants to be constantly varying their output resulting in extra wear and tear as well as network management issues.

The sudden loss of production can also be made up with gas turbine "peaking" generators but that tends to be very expensive, especially at times of peak demand.

Sources of electricity in Australia

Table 1 and Figure 1 show the actual sources of electric-

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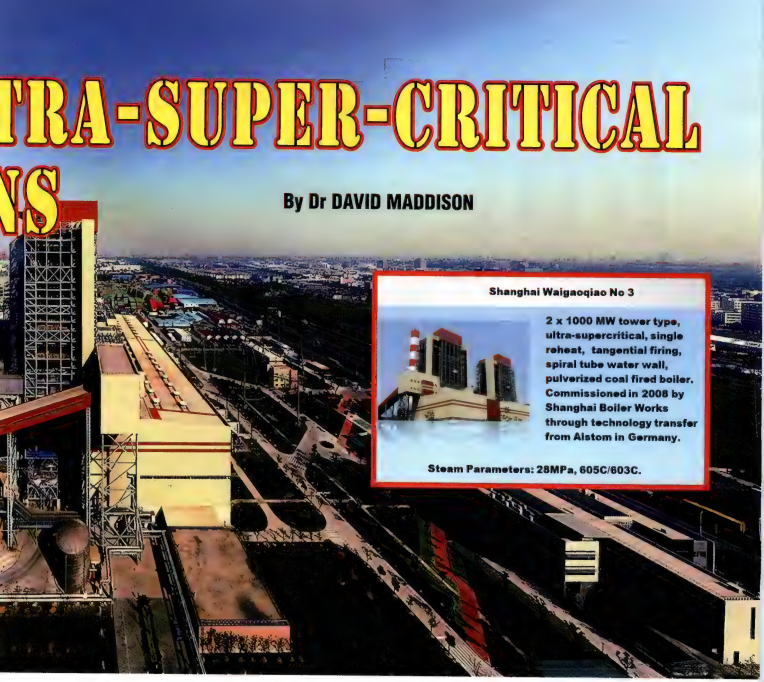
By Dr DAVID MADDISON



ity that are used in the National Electricity Market (NEM) which is Australia's wholesale electricity marketplace and its associated transmission grid. It is the largest interconnected power grid in the world with an end to end distance of over 5,000km and 40,000km of circuit in the grid.

Eleven billion dollars worth of electricity are traded each year to 19 million consumers, however it currently excludes WA and the NT.

GENERATOR TYPE	CAPACITY (% of total generation)	OUTPUT (% of total generation)
Black coal	39.2	50.8
Brown coal	14.3	25.7
Gas	20.1	11.6
Hydroelectric	16.5	6.6
Wind	6.6	4.8
Liquid fuel	1.7	0
Other	1.5	0.5

PRODUCTION TYPE (percent of total production)	OUTPUT PRODUCED
Fossil plus hydro (traditional 24/7 steady state production)	94.7
Fossil only	88.1
Existing traditional renewable (hydro)	6.6

Table 1: Data from the Australian Energy Regulator for financial year 2014/15 showing source of electricity and contribution to total generation capacity in the wholesale National Electricity Market (NEM). Note that the contribution of solar and other sources is so small in the wholesale market that it does not have a separate category. It can be seen that a vast majority of power in the NEM is derived from fossil and hydro production. The proportion of fossil fuel production (brown and black coal, gas) is also shown with the contribution due to traditional renewable hydro.

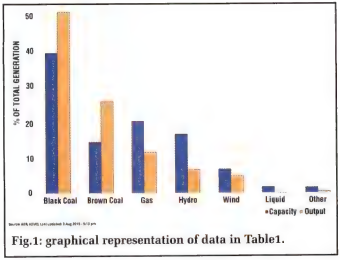


Fig.1: graphical representation of data in Table1.

Our requirement for base load production from fossil fuels and hydro is not going to go away and it can be seen from Table 1 that 94.7% of wholesale electricity comes from coal, gas and hydro generation. Coal itself is responsible for 76.5% of Australia's total power contribution to the national grid.

New coal-fired technology

While coal-fired power stations are an established technology, engineers have been working to improve their efficiency so that they use less coal to produce the same amount of electricity and as a consequence, produce less carbon dioxide. The benefit to the consumer is potentially lower prices due to the consumption of less fuel to make electricity.

The new developments in thermal power stations are super-critical and ultra-supercritical steam technology, fluidised bed combustion and integrated combined cycle gas turbine technology.

A 1% improvement in the thermal efficiency of a conventional coal-fired power plant actually gives a 2-3% reduction in carbon dioxide emissions so for this reason alone the idea is saleable to politicians and certain voters who believe in "anthropogenic global warming" but the economic justification is less fuel consumption.

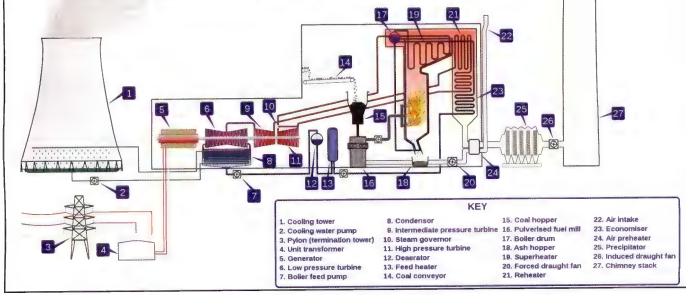
In fact, if the average efficiency of coal plants worldwide could be increased from 33% to 40%, two fewer gigatonnes of carbon dioxide emissions would be emitted (or produced) worldwide. This amounts to about what India emits.

Super-critical steam technology

In a typical coal power plant as shown in Figure 2, coal is pulverised to the consistency of talcum powder and blown into a "pulverised coal (PC)" burner in the boiler. The heat from the burner converts water to steam to drive a turbine which spins a generator. Once the steam has been through the turbine it is much cooler and is condensed, then goes back to the boiler to be reheated.

In reality, the path of the steam is more complicated but that is the basic principle. Steam turbines are massive, weighing hundreds of tons and spinning at 3000 RPM for 50Hz systems.

Fig.2: a typical sub-critical coal fired power station. Coal enters via a conveyor belt (14) and into a hopper (15) and is pulverised to a talcum powder-like consistency in a mill (16). The powder is mixed with air and blown into the furnace where it is burned, heating water or steam in the furnace tubes whereby it is passed to the boiler drum (17) where any water is separated from the steam. Steam from the boiler drum is then passed to the superheater (19) where it is rapidly heated to 540°C and around 165bar (16.5MPa, 2400 psi) of pressure. This steam then goes through the high pressure turbine (11) and then is returned to the reheater (21) after which is passed to an intermediate pressure turbine (9) and from there to the low pressure turbine (6). The steam is then passed to the condensor (8) which is cooled by water from the cooling tower whereby it rapidly condenses. The water is then pumped to the economiser (23) where it is preheated before returning to the boiler drum. Exhaust from the boiler passes through an electrostatic precipitator (25) and possibly other pollution controls before being vented into the chimney stack (27). Acknowledgement for graphic: By BillC under GNU Free Documentation License.



BOILING TEMPERATURE	PRESSURE (atmospheres or bar)	LATENT HEAT OF VAPORISATION (kJ/kg)
100°C	0	2256
150°C	4	2110
200°C	14	1942
254°C	41	1691
304°C	90	1356
351°C	165	884
374°C	220	0

Table 3: data from Lalonde Systhermique saturated steam table showing how the boiling point of water increases with increasing pressure and how the amount of energy required to vaporise water diminishes with increasing pressure until it gets to zero at the supercritical point.

A pulverised coal burner in action!

Want to see what a pulverised coal burner in the open looks like in action? It's worth a look! The still above is from a video in a Third World country (OH&S rules not in force!). See "*Coal Powder Burner Part 1*" https://youtu.be/XitLs7y5P78; also see "*Pulverised Coal Burner*" https://youtu.be/s0Ntd84EhfU

It's all about temperature and pressure

Depending upon their operating temperatures and pressures, coal-fired power plants are classified as sub-critical (traditional plants), super-critical or ultra-supercritical.

Super-critical technology involves the use of steam at a temperature and pressure above its so-called "critical point". The critical point of a fluid such as water is that point at which there is no distinct liquid or gaseous (steam) states.

A super-critical fluid is a special state of matter beyond the familiar solid, liquid and gas phases. For water, this occurs at a temperature of 374°C and a pressure of 22.31MPa or 220.15 atmospheres (3,235 psi) (the quoted pressure varies a little for some reason).

A power plant can operate more efficiently with supercritical steam because the additional energy required to achieve the higher operating temperatures is proportionally less than that required to reach sub-critical temperatures. (More details in the panel on page 35).

To understand the advantage of operation under supercritical conditions consider what happens to water when it is heated at normal atmospheric pressure. It will heat until it gets to the boiling point of 100°C. At that point, bubbles of steam start to form and are released into the atmosphere but the temperature of the water does not increase. The temperature of boiling can only be increased in a pressure vessel which allows the steam to be "superheated" beyond 100°C.

As the pressure is increased, the boiling temperature increases but the energy required for boiling (the latent heat of vaporisation) becomes less (see Table 3). A point is reached where the energy required for vaporisation diminishes to zero. This is the super-critical temperature and pressure.

The advantages of super-critical steam in power plants have been known for a long time but it has not been possible to fully implement the technology due to the special materials required to withstand the high temperatures and pressures.

Conventional steam power plants operate at a pressure of around 165bar (16.5MPa or 2393 psi) and are called sub-critical.

New generation super-critical power plants operate at pressures of around 243bar (24.3MPa or 3530 psi) and steam

	Sub-critical	Supercritical	Ultra-supercritical
Efficiency	33-37%, 34% typical	37-40%, 38% typical	43% with up to 46% being targeted.
Efficiency if CO_2 capture employed	25%	29%	34%
Steam temperature	Below 550°C, typical 540°C	565°C	Above 565°C, up to 610°C; 700-720°C being targeted.
Steam pressure	Below 22MPa or 3200 psi, typical 16.5MPa or 2400 psi	24.3MPa or 3530 psi	To 32MPa, 4640 psi; 36.5-38.5MPa, 5300-5600 psi being targeted.
Coal consumption	208,000 kg/h	185,000kg/h	164,000kg/h
Air consumption	2,500,000 kg/h	N/A	1,940,000kg/h
Ash produced	22,800kg/h	N/A	N/A
Desulphurisation products (used for building materials)	41,000kg/h	N/A	N/A
Stack gas	2,770,000kg/h @ 55°C	N/A	2,200,000kg/h
CO_2 emitted	466,000kg/h	415,000kg/h	369,000kg/h
Representative electricity cost (US$)	4.84c/kWh	4.78c/kWh	4.69c/kWh

Table 4: some performance figures for a typical 500MW pulverised coal plant with HHV (higher heating value) coal for various technologies. If carbon dioxide capture is employed, efficiencies drop dramatically. The massive flow of materials through the plant is obvious.

Other types of heat generation used in power stations

Fluidised bed combustion

Typical coal-fired power stations use pulverised coal in their furnaces, as mentioned above. An alternative is fluidised bed combustion (FBC).

A fluidised bed is formed where particulate matter such as powder or sandy material is subject to conditions that make it act like a fluid. Typically this is done by a forcing a liquid or a gas through the particulate medium. In nature, quicksand is a type of fluidised bed. For a video of a fluidised bed see *"Fluidised Bed: Floating Duck"* **https://youtu.be/3BqVFGCUviY**

In FBC, coal or some type of biomass such as wood waste or any type of combustible rubbish is burned in a fluidised bed process. Unlike the pulverised coal (PC) process which requires high quality feedstock, FBC allows the burning of much lower quality fuel, including abandoned coal waste which contains non-combustible material such as dirt and rock.

FBC can either be non-pressurised or pressurised (PFBC). FBC systems are the most common but PFBC offer the advantage of producing a gas stream that can also be used to drive a gas turbine, in addition to heating steam, thus enabling a type of combined cycle system with steam and gas turbines.

Circulating Fluidised Bed (CFB) is another variant in which pollution reducing agents such as limestone are added to the fuel to minimise sulphur dioxide production. The lower operating temperatures of this process also minimise production of nitrogen oxides.

CFB can also efficiently burn low value "opportunity fuels" such as waste from bituminous coal mines, anthracite coal mine waste or petroleum coke. A video of related interest is *"Alstom Introduces the ultra-supercritical circulated fluidised bed (CFB) boiler"* **https://youtu.be/pDKvyUroaC8**

Combined cycle gas turbine technology (CCGT)

One way to improve efficiency is to use two sets of turbines so that waste heat from the first turbine can be captured and used a second time. There are two types depending on the source of the fuel, either those that generate gas from coal "Integrated gasification combined cycle (IGCC)" plants or those that run on natural gas "Natural gas combined cycle (NGCC)" plants. The overall thermodynamic efficiency of such systems can reach 50-60%.

Integrated gasification combined cycle (IGCC) plants

In IGCC plants coal is turned into a synthetic gas or "syngas" by combining it with oxygen and steam and heating it in much the same way as "town gas" (or producer gas) used to be produced. The resulting gas comprises mainly hydrogen and carbon monoxide and this is purified and used to drive a gas turbine which turns a generator.

Waste heat from the gas turbine exhaust is then used to generate steam which then passes to a turbo-alternator to generate more electricity. The term combined cycle refers to the combination of both gas and steam turbines. Efficiencies in the mid forty% and possibly up to fifty% are possible but reliability issues inhibit commercialisation. A typical design is shown below.

Natural gas combined cycle (NGCC) plants

An NGCC plant is much the same as an IGCC plant but uses natural gas as the fuel instead of gasified coal. Up to 60% efficiency is possible. Claimed advantages of NGCC plants are: less than half the capital cost of coal-fired plant; relatively short construction times and less than half the CO_2 emissions of coal plants.

In addition, natural gas can be piped and does not need a lot of handling infrastructure as does coal. See the video *"Natural Gas Combined Cycle (NGCC) plants"* **https://youtu.be/D406Liwm1Jc**

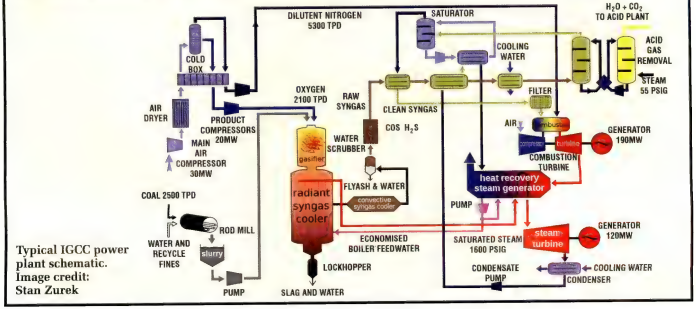
Combined heat and power (CHP) cogeneration

CHP produces steam to generate electricity and also provide steam or hot water for distribution to the local community or industry for heating purposes. CHP plants may burn coal, gas or any other suitable fuels, including waste products.

CHP plants are designed for flexibility of operation due to varying demands in summer and winter. High efficiencies of up to 80% are possible. Typically, these plants are only used in extremely cold areas such as Scandinavia and Eastern Europe.

See video *"CHP - Combined Heat and Power"* **https://youtu.be/2Kc6xKQIDIU**

A total of 95% efficiency is claimed for that plant.



Typical IGCC power plant schematic. Image credit: Stan Zurek

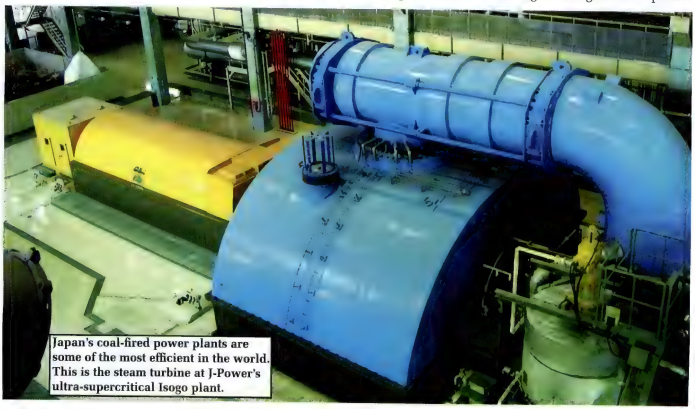
The John W. Turk Jr. Coal Plant, the first ultra-supercritical plant in the United States which came online in 2012.

temperatures of around 565°C (those figures vary a little depending on source). Note that steel starts to glow red at around 480°C so this ultra-hot steam is causing the metal to glow! Some performance specifications of plants with various steam technologies are shown in Table 4.

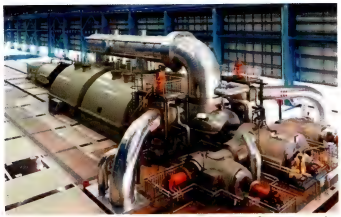
Super-critical steam plants generally use a different type of boiler (or more correctly, steam generator as no actual boiling takes place in the super-critical condition). This is known as a "once through" steam generator instead of the more traditional drum or recirculation type boiler generally used by sub-critical power stations (once through the boiler before reaching the turbines, although the water does pass back through the boiler after it is condensed).

A drum boiler operates below the super-critical pressure and water is recirculated through it and a "steam drum" is used to separate water from steam. The steam is removed for power generation and any water separated by the steam drum is recirculated through the boiler to be turned into steam.

A super-critical once-through steam generator operates



Japan's coal-fired power plants are some of the most efficient in the world. This is the steam turbine at J-Power's ultra-supercritical Isogo plant.



Alstom have recently announced a 1200MW ultra-supercritical plant for Dubai, scheduled to come on line in 2021.

above the critical temperature and pressure and no steam drum is required because the super-critical steam is a single phase with no separation of water and steam necessary.

Drum boilers have a greater wall thickness than once-through steam generators, making them slower to start or change operating conditions. Once-through boilers also have less working fluid in them which again makes them more responsive to changes in operating conditions.

Once-through boilers require more sophisticated controls than drum boilers as changing load demand is met by varying both fuel and feed water flow simultaneously, while in drum boilers only the fuel flow needs to be controlled.

Other improvements in efficiency are also possible such as with the use of reheat technology whereby steam from the first stage of the steam turbine is fed back to the steam generator for reheating a second time and also heat extraction from exhaust gases. Siemens say that their turbines can approach 50% efficiency with reheat stages.

Pressurisation of boilers or steam generators is maintained via the boiler feedwater pump which returns condensate back to the boiler at high pressure.

Turbines and generators designed for super-critical steam technology are much the same as with subcritical designs but consideration must be made for the much higher steam pressures and temperatures and the ability to alter conditions to accommodate for varying loads, which is less possible than for sub-critical designs as the sub-critical drum type boilers take longer to ramp their output up or down.

Steam turbines usually consist of three main sections: high pressure, intermediate pressure and low pressure. These consist of sets of blades similar to what is found in a jet engine. As steam expands through the sets of blades it causes rotation of the turbine about its axis.

In the high pressure section, steam from the steam generator enters the turbine, expands causing the turbine to rotate and then, in reheat installations, is returned to the steam generator for further heating before being passed into the intermediate pressure section.

In the intermediate section the steam further expands causing further rotation of the turbine assembly when it is finally passed to the low pressure section. After the low pressure section, the spent steam and condensate is passed through to the condenser where remaining steam, which is much below atmospheric pressure, is converted to liquid and then it is returned to the steam generator.

Life cycle costs of super-critical steam plants are only 2% higher than for sub-critical but their fuel costs are much less than that, so it is an economic proposition to invest in this technology.

CSIRO's Super-critical Solar Thermal Power Plant

Super-critical steam is not only of benefit in fossil fuel plants but can also be utilised elsewhere where efficient production of steam is required. Australia's CSIRO is developing a solar thermal power station that uses 600 sun-tracking mirrors (heliostats) to direct solar energy from the sun into a "receiver" containing steam tubes at the top of a tower as shown below.

The steam generated is used to drive a turbo-alternator. The steam produced, being at a super-critical pressure of 235Bar (23.5MPa or 3408 psi) and a temperature of 570°C is a world record for super-critical steam production outside of fossil fuel thermal plants and enables more power to be produced for the same amount of sun compared to similar sub-critical plants.

For a video on this plant see "*Super-critical solar steam*" **https://youtu.be/P4mFJG2f5bA**

"Solar Tower 2" at the CSIRO Energy Centre in Newcastle, NSW. It is a solar thermal plant that generates super-critical steam to drive turbines to produce electricity. Image credit: CSIRO

First super-critical plant in 1957

The first super-critical steam power plant was built in 1957 in Ohio and was called Philo Unit 6.

You can read about the history of this unit and download a brochure at **www.asme.org/about-asme/who-we-are/engineering-history/landmarks/228-philo-6-steam-electric-generating-unit**

After the Ohio plant, super-critical steam cycles became more widely used in the US in the late 1960s and units were built through the 1970s and 1980s.

However, these were pushing materials technology of the time to the limit and problems were encountered such as boiler tube fatigue and creep of metal in the steam headers, steam lines and the turbines.

These problems caused a return to sub-critical technology with no incentive to return to super-critical technology due to the low price of coal and the extra construction cost of super-critical plant not being justifiable.

Conditions are different now and the materials problems have been solved, hence a greater incentive to use super-critical technology. There are over 400 super-critical units in use throughout the world at the present time.

Super-critical steam nuclear plants

Super-critical steam can also be used to improve the thermal efficiency of nuclear power plants; however the design of nuclear plants is extremely conservative and this technology is not commercially implemented at the moment. Nevertheless the super-critical water reactor (SCWR) is under active investigation worldwide as an advanced reactor technology as it offers a thermal efficiency of around 45% compared with around 33% for conventional commercial reactor designs.

In a nuclear reactor super-critical steam offers many advantages. Since there is no chaotic boiling of water with super-critical steam, the internal reactor environment is much more uniform with no bubbles so this allows much better heat and fluid flow.

Also, because there is no longer a mixture of steam and water in the reactor, many steam-related components can be eliminated such as the pressuriser, steam generator, various pumps, steam separator and driers.

Super-critical steam is also less of a neutron moderator (meaning faster neutrons) than water allowing for the possibility, in some designs, of a fast neutron reactor which could utilise Uranium-238 (which comprises 99.3% of the uranium present in nature) instead of the much rarer Uranium-235 (0.7% present in nature).

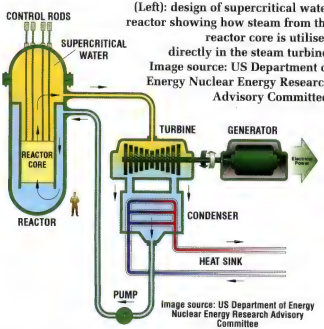
The better heat flow and faster neutrons with super-critical steam allows a smaller core and an overall smaller reactor reducing construction costs. A fast neutron reactor also allows for long-lived radioactive products to be "transmuted" to shorter-lived ones.

Due to the greater efficiency of an SCWR more power can be produced with the same amount of nuclear fuel as a conventional reactor meaning a greater fuel economy and lower costs.

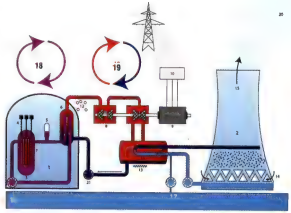
Finally, in an SCWR super-critical steam from the reactor is fed directly to the steam turbine much as in the straight through steam generator previously mentioned, unlike conventional reactors where the steam from the reactor heats a secondary steam circuit connected to the steam turbine. This results in a much more simple and lower cost design.

Of course, there are also some challenging design issues with the SCWR.

Among these are the development of materials that can reliably withstand the high pressures and temperatures of the super-critical steam in a radioactive environment; less cooling fluid in the reactor which reduces the ability to absorb heat from transient events and due to coolant loss in a malfunction; and a change in the moderating properties of the coolant between the steam outlet and the steam inlet due to it being cooler and more dense upon its return. Solutions to all these problems are under development.



(Left): design of supercritical water reactor showing how steam from the reactor core is utilised directly in the steam turbine. Image source: US Department of Energy Nuclear Energy Research Advisory Committee.

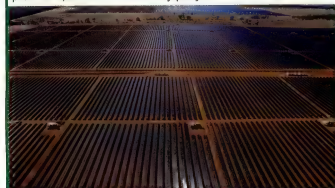


Above: a typical boiling water pressurised reactor. Note the primary (18) and secondary (19) steam cycles. In contrast, in an SCWR, super-critical steam is sent directly from the reactor to the steam turbine. Image: Steffen Kuntoff

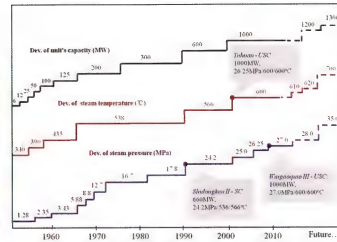
Australia's largest electricity plants

In Australia, when comparing the size of electricity generation projects, reference is sometimes made to the Bayswater Power Station (above) in the Upper Hunter Region of NSW. This is a coal-fired power station that was commissioned from 1985, with four 660 megawatt generators for a total capacity of 2,640MW. It produces about 17,000GWh of electricity per year and its expected service life is 50 years.

In comparison to the Bayswater plant, Australia's (and the Southern Hemisphere's) largest wind plant is the Macarthur Wind Farm, in western Victoria. It has a 420MW "nameplate capacity" but a 35% capacity factor as the wind does not blow all the time, hence an average power output of 147MW. It, like most wind plants has an expected service life of 25 years and is expected to produce 1,250GWh of electricity per year.



Another large scale alternative energy plant is Australia's largest solar array near Nyngan, NSW, which has a capacity of 102MW at full power and is expected to generate 235GWh of energy per year.



Development of China's coal thermal power station technologies. Image source: "Current Status and Outlook of SC & USC Power Generation Technology in China", Electric Power Planning and Engineering Institute, 23 February 2012.

All of Australia's coal-fired power stations are sub-critical but Bayswater has plans for a conversion to super-critical technology, although those plans seem to be on hold at the moment. There is also development approval for a Bayswater B power station which would be 2000MW and use either combined-cycle gas turbine technology (CCGT) or ultra-supercritical coal however this approval has been pending since 2009 and there is no construction yet.

Similarly, there is development approval for the Mt Piper (NSW) Power Station Extension for CCGT or ultra-supercritical coal technology, also for a 2000MW station which was approved 2010 but again, there is apparently no action.

Australia's 22 sub-critical power stations have a total generating capacity of 24,608MW with an average age of 30 years.

Worldwide, the focus on new coal-fired power stations, where they are permitted to be built, is for super-critical and ultra-supercritical operation due to greater fuel economy and lower CO_2 and other emissions.

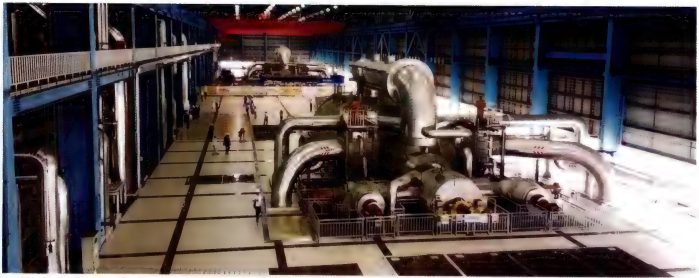
The John W Turk Jr. Coal Plant in Arkansas, US was finished in 2012 and was the first ultra-supercritical coal plant in the USA. It is rated at 600MW and runs at a steam pressure of 31MPa or 4500 psi and a temperature of over 600°C. Compared with an equivalent sub-critical plant it uses 163,000 tonnes less coal and produces 290,000 fewer tonnes of CO_2 per year.

Unfortunately, because of restrictive and ever-changing environmental laws in the USA, it may be the last. See YouTube video "*Arkansas Ultra Supercritical Coal Plant Technology Faces Extinction*" **https://youtu.be/QJXiGI-CSYM**

For a look at a German super-critical steam plant see "*RDK 8 (Germany) supercritical steam power plant*" **https://youtu.be/fJVhwg5o0vA**.

China's thermal power station development

While the regulators and activists of the Western world are increasingly opposed to coal, the developing world such as China and India have no such inhibitions. China is currently building the equivalent of two 500MW coal plants each week and adding about the capacity of the UK power grid each year.



Inside the turbine hall of China's Waigaoqiao No.3 ultra-supercritical power station in Shaghai, with two Siemens-designed 1000MW ultra-supercritical generators, with the steam generation plant designed by Alstom.

As well, they are they are now the biggest suppliers of thermal power station equipment in the world. In 2014 alone they added an astonishing 101GW of generating capacity, more than the total installed capacity of all but ten nations.

Interestingly, China acquires their thermal coal technology via license arrangements or joint ventures with Western and Japanese companies such as Alstom, BHK, Siemens, Mitsui-Babcock, Mitsubishi and Toshiba. The graph opposite shows the extraordinary development of China's coal thermal power station technology in terms of unit capacity, steam temperature and steam pressure.

China is focusing on super-critical and ultra-supercritical power stations, an example of which is the Waigaoqiao No. 3 plant with two 1000MW ultra-supercritical units. In this plant the Shanghai Electric Co. supplied the steam generation under license from Alstom and the turbines under license from Siemens.

This plant (shown above and on pages 26 & 27) operates at 600°C and 276bar (27.6MPa or 4,000 psi) and had a thermal efficiency of 42.7% when opened in 2008 but that increased to 44.5% in 2011 due to plant improvements and is now one of the most efficient coal plants in the world.

Conclusions

Despite claims to the contrary, the age of fossil fuel is not over yet; at the moment there appears to be no genuinely economic alternative to our cheap and reliable base power from fossil fuels or nuclear in some countries (and an even more questionable need to replace it).

New technologies such as super-critical and ultra-supercritical steam are significantly improving the efficiency of coal plant, while new developments in fossil fuel production are able to provide us with cheap and reliable electrical energy with less fuel use and lower emissions for many decades into the future. SC

Super-critical efficiency gains

To understand why a super-critical plant is around 4% more efficient than a sub-critical plant we need to look at the losses in the system.

There are five main losses in a coal-fired power plant: incomplete coal combustion, energy lost transferring the heat of combustion to the working fluid (water/steam), heat energy which escapes from the working fluid in the boiler or piping, turbine inefficiencies and electrical losses in the alternators and wiring.

The first and last steps, coal combustion losses and electrical losses, are much the same in sub-critical and super-critical plants. The single biggest improvement in a super-critical plant is in the turbines.

Only about 1/3 the chemical energy in the coal burned is ultimately converted to electrical energy and of the 2/3 of the original energy lost, roughly half (or 1/3 of the total) is in the turbines, due to either friction or heat remaining in the exhaust.

The turbines in a super-critical plant operate at around 50% efficiency compared to 46% for a sub-critical plant or 54% for an ultra-supercritical plant. While the maximum theoretical (Carnot cycle) efficiency for super-critical temperatures is only ~1% higher, steam turbines are better approximated using the Rankine cycle where the much higher pressures lead to the 4% improvement, for an overall plant efficiency improvement of around 2%. This therefore explains about half the overall improvement (ie, from 34% to 38%).

Note that the fact that the fluid entering the turbines is in a super-critical state is only incidental, as it quickly turns to regular steam as the pressure drops through the turbine.

It's simply the higher input temperature and pressure which yields the higher efficiency.

The other 2% worth of efficiency gains are due to multiple factors. One is that the steam generator in a super-critical plant is much smaller than the drum boiler in a sub-critical plant. It therefore has less surface area and fewer pipes and protrusions and so loses less heat.

To give an idea of the contribution of the boiler/steam generator to overall efficiency, a typical boiler is around 86-88% efficient. About 40% of these losses are due to heat carried away in the flue gasses while some of the remainder is due to incomplete coal combustion.

The fact that the working fluid is heated closer to the coal combustion temperature (of over 1000°C) also means that more of the combustion energy is transferred to the working fluid.

High Visibility 6-Digit LED GPS Clock

Want a really bright 6-digit clock that you can see at a considerable distance? Would you like it to have GPS time precision with automatic time zone and daylight saving adjustment? Well, have we got a clock for you! This new clock design uses six 56mm-high LED digits which are so bright that they seem larger than they really are. And with optional GPS time-keeping, it would be ideal for those who are travelling around the country as well those who simply want a highly visible clock.

FOLLOWING ON from the 6-Digit Nixie Clock described in the February & March 2015 issues, we have had a number of enquiries from readers who want a modern clock (ie, without Nixies!) with GPS accuracy but also high visibility. So we have combined the GPS time-keeping features with a 6-digit LED display which comes in a range of colours: red, blue, yellow, green and emerald green. For sheer impact, we suggest that you go for the blue or the emerald green.

The unit can be wall-mounted or can sit on a desk. It runs from a 12-18V DC plugpack or power supply and has solid or flashing colons (at 1Hz).

With a GPS module, as long as the unit is placed where it can receive the satellite transmissions, all you have to do is power it up and it will show the correct time year-round – even after an extended blackout.

The unit is housed in a custom laser-cut 3mm clear or tinted acrylic case. The case incorporates two slots for screw heads to hold it on the wall as well as cut-outs for the pushbuttons and DC socket and holes for the piezo buzzer sound to exit the case.

An infrared remote control can be used to change the display brightness, show the date, set the time and alarm and also to use the unit as a timer. It can count up or down, showing fractional seconds for times under one hour and sound its piezo buzzer after a preset period. The same piezo buzzer is used for its 7-day alarm feature – a different alarm time can be set for each day and the alarm can be enabled or disabled for any given day.

The display can be set to 12 or 24-hour time, with or without leading zero blanking. Time is kept using an internal crystal which can be trimmed for long-term accuracy (not necessary if a GPS module is fitted). An on-board light sensor allows the display to automatically dim at night. Basic functions such as setting the time or showing the date can be performed using two on-board pushbuttons. All functions can also be performed using the infrared remote control.

All parts mount on a single PCB for easy construction and it's controlled by a PIC32 microcontroller with 512KB of flash memory. Most of this is taken up with geographic data which is used to determine the local time zone and daylight savings rules, based on the GPS co-ordinates.

Most GPS modules are suitable and start at just $10 – we mention some possibilities later in the article.

Circuit description

The complete circuit of the GPS-

The completed clock is shown here fitted with blue 7-segment LED displays but red, yellow, green and emerald green displays could also be used. The finished clock measures 308 x 36 x 76mm and fits into a laser-cut transparent Perspex case.

By Nicholas Vinen

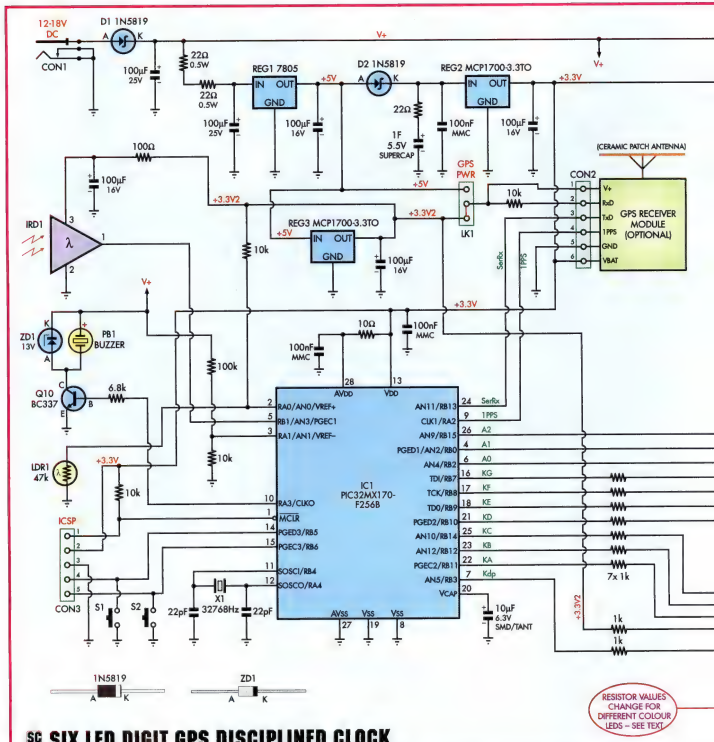
disciplined LED clock is shown in Fig.1. The digit anodes are driven by MPSA13 monolithic NPN Darlington transistors Q20-Q25 which are configured as emitter-followers (ie, current buffers) which are in turn driven by the outputs of a single HEF4028 CMOS decimal decoder, IC2. The Darlingtons are required due to the very weak drive capabilities of IC2 (~1mA). IC2 drives one of its B0-B9 outputs high and the others low, depending on the states of the S0-S3 inputs. For "invalid" input combinations, all outputs are low.

An HEF4028 is used rather than a regular 4028B due to its higher maximum voltage rating (18V vs 15V), giving more flexibility in matching the DC supply voltage to the LED display requirements.

IC2's inputs are controlled by level shifter IC3, a 40109 which is also a CMOS device. The VDD pins of IC2 and IC3 connect to the main DC supply of around 15V while IC3's VCC pin connects to the 3.3V supply which is also used by the microcontroller. Thus, the micro's 3.3V outputs are suitable for driving IC3's A, B & C inputs, which are then level-shifted to 0-15V signals at pin 4 (OA), pin 5 (OB) and pin 11

Features & Specifications

- Choice of six display colours: blue, emerald green, red, green, yellow or white
- Optional GPS module for automatic time zone determination and daylight saving
- Housed in custom laser-cut wall-mounting transparent acrylic case
- Adjustable brightness
- Automatic dimming based on ambient light
- Date display (via pushbutton/remote control)
- Manual time zone override with GPS module
- Keeps time for over one hour during blackout
- Power consumption: depending on display colour, ~100-500mA @ 12-18V
- Some colour versions suitable for use with 12V automotive supply
- Also operates as count-up/count-down timer with sub-second resolution
- 7-day alarm with piezo buzzer
- Functions can be controlled with universal infrared remote



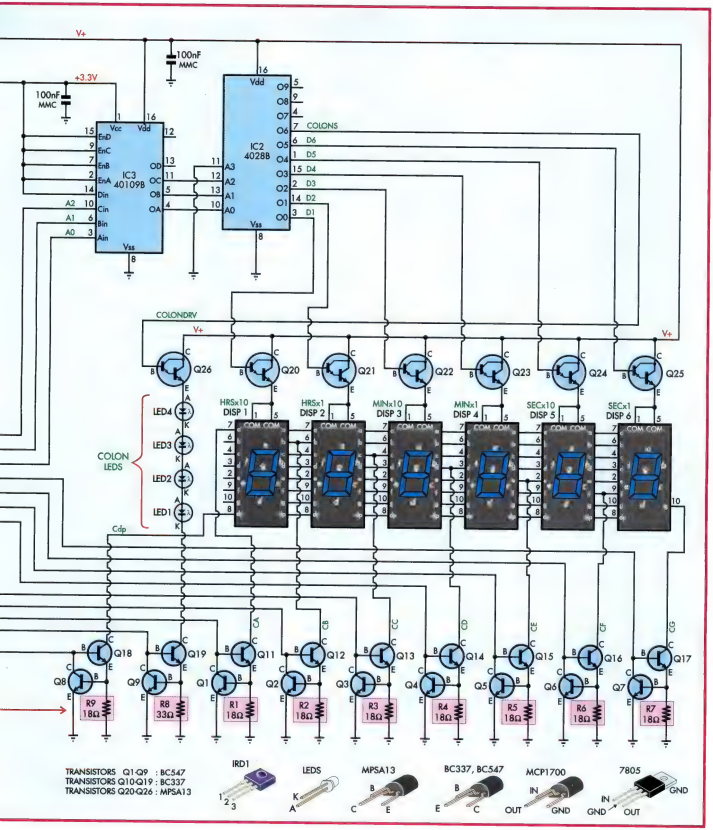
SC SIX LED DIGIT GPS DISCIPLINED CLOCK

Fig.1: the LED clock circuit is based around 32-bit microcontroller IC1. It drives the 7-segment display anodes via level shifter IC3, decimal decoder IC2 and Darlington transistors Q20-Q26. The cathodes are driven by NPN transistors Q1-Q9 and Q11-Q19. The power supply includes 5V and 3.3V rails to run the optional GPS module plus a supercapacitor-backed 3.3V rail for the microcontroller.

(OC) to control IC2.

IC3's enable pins are all tied high to Vcc, so these outputs are always active. If the micro wants to disable drive to the digits, it simply sets IC3's inputs A, B & C high which causes output O7 (pin 4) of IC2 to be selected. B7 is not connected to anything so all the Darlington transistors are switched off. Output pins O0-O5 select digits DISP1-DISP6 while output pin O6 drives Darlington Q26 which powers the four discrete colon LEDs.

Each of the seven segment cathodes, including the decimal point, is switched by the micro, using a separate control pin to power an NPN transistor (Q11-Q18) operating as a common-emitter amplifier. These are combined with emitter resistors and additional NPN transistors (Q1-Q8) which limit



the current through each segment when that segment is enabled.

For example, if segment A of the current digit is to be lit, output RB11 (pin 22) of microcontroller IC1 is driven high. This provides base current to Q11 which sinks current from the segment A LED string within that digit. Once this current rises to approximately 30mA, there is enough voltage across the 18Ω emitter resistor to forward-bias Q1's base-emitter junction, shunting any additional base driven current away from Q11 and to ground.

Since the decimal points are physically smaller than the other segments, the associated emitter resistor value is higher (eg, 33Ω), reducing the relative current and thus providing visually similar brightness levels. The colon LEDs have a similar cathode driving

Parts List: High-Visibility 6-Digit LED GPS Clock

1 double-sided PCB with plated through-holes, coded 19110151, 302 x 70mm
1 set of laser-cut transparent acrylic pieces to make case*
1 small tube acrylic adhesive
1 3.3V or 5V GPS module (optional; up to 200mA draw, TTL interface preferred)
1 mini TO-220 flag heatsink (6073B type, for REG1)
1 8-way pin header, 2.54mm pitch, snapped into 3-pin & 5-pin sections (CON3,LK1)
1 jumper shunt (LK1)
1 32.768kHz watch crystal (X1)
1 mini 9-14V piezo buzzer, 7.62mm pin spacing (PB1) (Jaycar AB3459, Altronics S6105)
1 47-100kΩ LDR (LDR1)
2 right-angle tactile switches, 4.5mm-long actuators (S1,S2)
1 28-pin narrow DIL socket
2 40-pin socket strips
1 PCB-mount DC socket to suit power supply
1 M3 x 10mm machine screw, flat and shakeproof washer plus nut
4 4G x 6-9mm self-tapping countersink head screws
1 60mm length foam-cored double-sided tape (optional, for attaching GPS module)
4 small stick-on rubber feet (optional, for desktop usage)
1 universal remote control

Semiconductors

1 PIC32MX170F256B-I/P 32-bit microcontroller programmed with 1911015A.hex (IC1)
1 HEF4028 BCD to decimal decoder CMOS IC (IC2)
1 40109B CMOS quad level-shifter IC (IC3)
1 3.3V infrared receiver (IRD1)
1 7805 5V 1A linear regulator (REG1)
2 MCP1700-3.3/TO micropower 250mA 3.3V LDO regulators (REG2,REG3)
9 BC337 NPN transistors (Q1-Q9)
10 BC547 NPN transistors (Q10-Q19)
7 MPSA13 30V 1.2A NPN Darlington transistors (Q20-Q26)
1 13V 1W zener diode (ZD1)
2 1N5819 1A 40V Schottky diodes (D1, D2)

Capacitors

1 1F 5.5V supercapacitor
6 100µF 25V electrolytic, maximum height 11mm
1 10µF 4V SMD ceramic (1206) or tantalum SMD/through-hole capacitor
5 100nF disc or multilayer/monolithic ceramic
2 22pF disc ceramic

Resistors (0.25W, 1%)

1 100kΩ
4 10kΩ
2 6.8kΩ (one optional, for RS-232 GPS modules)
9 1kΩ
1 100Ω
3 22Ω 0.5W
1 10Ω

Additional parts for the blue display version

6 LBT23101BB blue 2.3-inch 7-segment LED displays* (DISP1-6)
4 5mm blue LEDs with diffused lenses* (LED1-4)
8 18Ω 0.25W resistors (R1-R7,R9)
1 68Ω 0.25W resistor (R8)
1 15-18V DC 500mA+ regulated power supply (eg, Jaycar MP3318, Altronics M8950)

Additional parts for the emerald green display version

6 LBT23101BGG emerald green 2.3-inch 7-segment LED displays* (DISP1-6)
4 5mm emerald green LEDs with diffused lenses* (LED1-4)
8 18Ω 0.25W resistors (R1-R7,R9)
1 68Ω 0.25W resistor (R8)
1 15-18V DC 500mA+ regulated power supply (eg, Jaycar MP3318, Altronics M8950)

Additional parts for the red display version

6 CAI23101BS or SA23-11SRWA red 2.3-inch 7-segment LED displays* (DISP1-6)
4 5mm bright red LEDs with diffused lenses (LEDs1-4)
8 18Ω 0.25W resistors (R1-R7,R9)
1 68Ω 0.25W resistor (R8)
1 12-15V DC 1A regulated plugpack or 12V power supply (eg, Jaycar MP3310, Altronics M8932A)

arrangement although since they can be controlled entirely by switching the anode supply, this is not controlled by the micro but rather enabled as long as the DC supply is present.

Timekeeping

The digits are multiplexed at around 100Hz by micro IC1, to avoid noticeable flicker. Crystal X1 is used to run its internal real-time clock and calendar (RTCC) for timekeeping. If a GPS receiver is connected via CON2, its serial data stream is received by IC1 at pin 24 and once sufficient data is available to determine accurate local time, the RTCC is updated and kept synchronised with the GPS data.

If the unit loses power, the GPS unit is powered down as it is supplied by either REG1 (if it runs off 5V) or REG3 (3.3V) and these are powered from the incoming ~15V supply from CON1 via D1. However, a 1F (one Farad) super capacitor is charged from REG1's output via Schottky diode D2, to around 4.7V. This capacitor powers micropower low-dropout 3.3V regulator REG2 which supplies microcontroller IC1 and the GPS unit's memory backup (if required).

The micro detects a loss of power by monitoring the voltage at its AN1 input. If the 15V rail drops below 7V (the voltage required to keep the supercap charged), it immediately switches off all the LEDs and goes into a low-power sleep mode while keeping its RTCC active. It wakes up every few seconds to check if power has been restored and if so, resumes displaying the time.

If a GPS receiver is present, after some time (usually a minute or so), it will regain satellite lock and the time will be re-synchronised. However, given that the supercap charge will only last a few hours, it's unlikely the RTCC will have drifted more than a small fraction of a second during this time.

Infrared receiver IRD1's output is connected to input RB1 of IC1 (pin 5)

Additional parts for the white display version

6 LBT23101BW white 2.3-inch 7-segment LED displays (DISP1-6)
4 5mm white LEDs with diffused lenses (LED1-4)
8 18Ω 0.25W resistors (R1-R7,R9)
1 68Ω 0.25W resistor (R8)
1 15-18V DC 500mA+ regulated power supply (eg, Jaycar MP3318, Altronics M8950)

Additional parts for the yellow-green display version

6 LBT23101BG green 2.3-inch 7-segment LED displays* (DISP1-6)
4 5mm bright green LEDs with diffused lenses (LEDs1-4)
7 5.6Ω 0.25W resistors (R1-R7)
2 22Ω 0.25W resistors (R8,R9)
1 15-18V DC 500mA+ regulated power supply (eg, Jaycar MP3318, Altronics M8950)

Additional parts for the yellow display version

6 LBT23101BY yellow 2.3-inch 7-segment LED displays (DISP1-6)
4 5mm yellow LEDs with diffused lenses (LED1-4)
7 5.6Ω 0.25W resistors (R1-R7)
2 22Ω 0.25W resistors (R8,R9)
1 15-18V DC 500mA+ regulated power supply (eg, Jaycar MP3318, Altronics M8950)

* Available from the SILICON CHIP online shop

and so a universal remote can be used to set the time and control the unit, allowing it to be used as a timer as well as a clock. The remote can also be used to set an alarm. In the absence of a remote control, pushbuttons S1 & S2 can be used to perform basic tasks such as setting the time. When pressed, these pull down inputs RB5 and RB6 (pins 14 & 15) which are also used initially to program IC1 via CON3.

IC1 can activate a piezo buzzer by bringing its RA3 output (pin 10) high. This supplies current to the base of NPN transistor Q26 which then sinks current from the buzzer's negative terminal. ZD1 limits the voltage applied across the buzzer, while the current through Q26 is limited to a safe level by its 6.8kΩ base resistor.

Microcontroller IC1 uses LDR1 to monitor the ambient light level and adjust the LED brightness to suit. LDR1 forms a voltage divider across the 3.3V supply in combination with a 10kΩ resistor and thus the voltage at pin 2 of IC1 (AN0) varies depending upon the amount of light falling on LDR1. The top of this divider is connected to REG3 so it doesn't draw power from the supercap via REG2 when the main supply is off.

REG1 is fitted with a flag heatsink; while the circuit does not draw a great deal of current from the regulator, the voltage across it can exceed 10V. The two 22Ω resistors in series with the input reduce regulator dissipation by up to half a watt. D1 provides reverse supply polarity protection while minimising voltage drop.

Most LED displays we tested worked best when the clock was driven by a regulated DC supply of 15-18V. Lower voltages can be used, down to around 12V (depending on the exact displays used), however maximum brightness and display uniformity may not be quite as good. For lower supply voltage, red is the safest display choice.

Software operation

The micro's hardware Real Time Clock and Calendar (RTCC) is used for timekeeping, in combination with an external 32.768kHz crystal. If a GPS unit is present, when a valid time is received via the serial port, it is compared against the RTCC which is moved forward or back if necessary to keep correct time.

Display multiplexing is performed using a timer interrupt so that if the micro is busy doing some processing (eg, geographic searching to determine your time zone) it won't interfere with the display. Infrared reception is similarly interrupt-based, however this uses a pin change interrupt as well as a timer to measure infrared pulse duration.

For details on how the GPS latitude/longitude information is used to search an extensive geographic database for time zone determination, see the explanation on pages 34 & 35 of the February 2015 issue. We re-used this part of the code from the Nixie Clock project, along with the geographic data. There were some bugs in the original Nixie Clock code in handling some time zones and the fixes have been incorporated into this project.

We used some other lessons learned in the design of the Nixie Clock when designing this project. For example, we've connected the LDR to the 3.3V supply which is not derived from the 1F supercapacitor, to increase the time that the supercap lasts in a blackout. We changed D2 to a Schottky type for the same reason. Originally we used a standard diode for this role due to the much lower reverse leakage but it turns out that the lower forward voltage of the Schottky diode more than makes up for this.

Choosing a GPS module

You need a GPS module that will fit in the space available but also with good sensitivity as it must work well indoors. Many such modules are available at surprisingly low prices.

The GlobalSat EM408 we used in our prototype (US$17.81) has a tracking sensitivity of -159dBm while the more expensive Fastrax UP501 is -165dBm (ie, better). We found a VK16E (-159dBm) on Ali Express for US$8.79 and a u-blox Neo-6M (-161dBm) for US$10.42.

Other differences between modules are: TTL or RS-232 signalling, 4800 or 9600 baud, whether it has an onboard battery back-up, whether it has a 1PPS output and whether there's an enable pin and how it's driven. TTL is preferred over RS-232 as RS-232 requires a resistor to be added in series with the TX pin of the module. The software will automatically detect the baud rate.

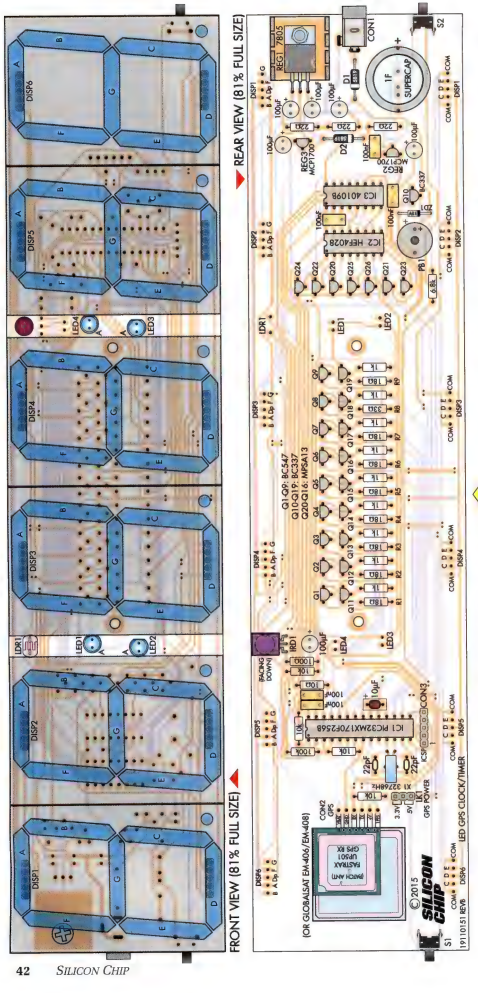
Whichever module you choose, you will need to check the data sheet to determine these factors and its pinout.

A 1PPS output is desirable and gives the most accurate time but is not vital. Onboard battery back-up will let the module ride out longer black-outs but modules without can have VBAT connected to the supercap so that it doesn't have to go through a slow cold-start each time it powers up.

Many modules have no enable pin or if they do, it may be left floating. However, the EM408 we used required a pull-up resistor between its enable input and its power supply so we soldered one onto the pin header. It looks a bit messy but does the job.

Construction

The first step in the assembly is to fit the control components to the back



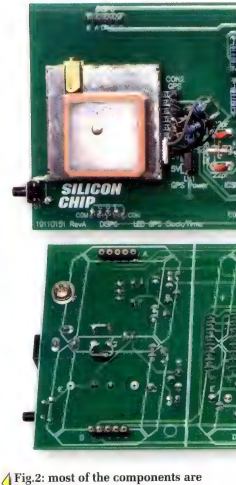
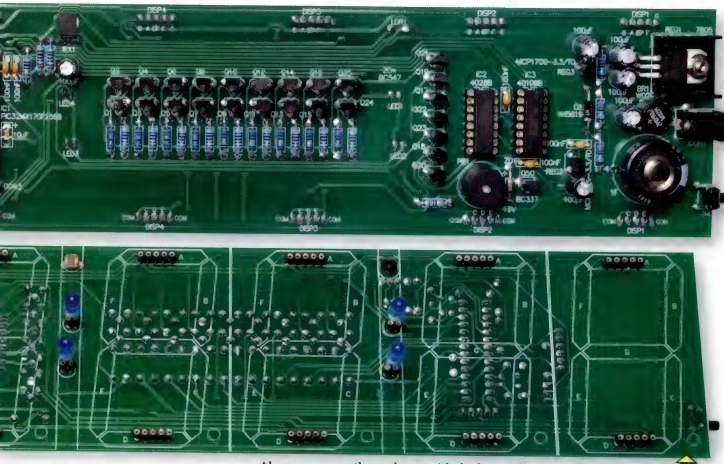


Fig.2: most of the components are fitted to the rear of the PCB. Note that the values of resistors R1-R9 are varied to suit the 7-segment LED displays used and that the 10µF capacitor can be either an SMD ceramic (as in our photos and recommended) or a through-hole tantalum type. The six large displays are mounted on the front of the PCB via socket strips, along with the LDR for ambient light sensing and four discrete LEDs which form the colons between the hours, minutes and seconds. IRD1 is mounted on the back of the PCB but "peers" through a hole between the minutes and seconds displays.

of the PCB, as shown in Fig.2. Start with the resistors; it's best to check each batch with a DMM before fitting them although you can also use Table 1 as a guide. Remember to change the resistor values to suit the display colour you're using (see parts list).

Follow with the two Schottky diodes, orientated as shown in Fig.2, then zener diode ZD1. Then fit the socket for IC1, with the notch at the top as shown. The watch crystal can go in next; be careful since its leads are very thin. Bend them so that the



Above: compare these photos with the layout diagrams (Fig.2) when building the unit. Note that our prototype used an RS-232 GPS module. This meant that we had to install a couple of extra 6.8kΩ resistors (see text).

crystal can lie flat on the board without the leads touching the metal can and solder a resistor lead off-cut to the pads on either side after bending it tight over the can to hold it down.

Next, bend REG1's leads down by 90° exactly 5mm from its body and attach it to the PCB with a flag heatsink wedged in-between. The head of the M3 machine screw goes on the other side of the PCB, with a flat washer under the screw head and a shakeproof washer under the nut.

Do the screw up tightly and make sure that the heatsink is straight and that the regulator pins pass through the appropriate mounting holes before soldering and trimming the three leads.

Now solder IC2 and IC3 in place. Be very careful to get the orientation correct (pin 1 at upper-left) and don't get them mixed up as it's very difficult to de-solder DIL ICs from a plated-through board. You could use sockets, as we did for our prototype, however direct soldering provides better reliability.

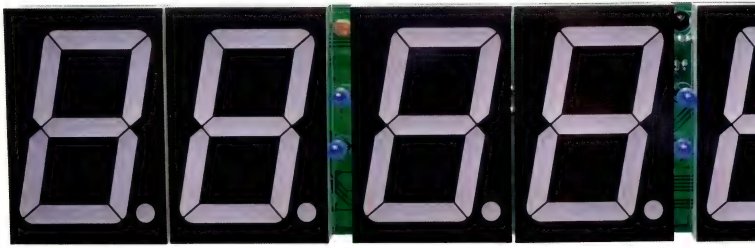
The ceramic capacitors can go in next, followed by the transistors. There are 26 in total and three different types, so don't get them mixed up. Fig.2 shows the position and orientation of each. You will probably need to crank the leads out in each case, which is easy to do with a small pair of pliers. The two MCP1700 regulators can then go in, using the same procedure.

Now fit the two pushbuttons at either end of the PCB, making sure they are pushed all the way down onto the board before soldering them. Follow with the DC socket (the same comment applies). The two pin headers can then be soldered in place, followed by the remaining capacitors.

Watch the electrolytic and tantalum (if used) capacitor polarity, especially the supercap, as you may need to check its markings carefully to figure out which terminal is positive and which is negative. Three sets of holes are provided for the supercap, to suit different lead spacings. Mount the piezo buzzer now; it's also polarised and the

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	4	10kΩ	brown black orange brown	brown black black red brown
❑	2	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	9	1kΩ	brown black red brown	brown black black brown brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	3	22Ω	red red black brown	red red black gold brown
❑	1	10Ω	brown black black brown	brown black black gold brown



LED Display Characteristics

The six 7-segment digits which form the clock display are in separate modules measuring 48 x 70 x 12mm, each with 10 pins. The digits themselves are 57mm tall and 32mm wide. Each segment consists of four series LEDs, except for the decimal points which comprise two series LEDs. Two of the 10 pins are the common anode connections while the remaining eight are the separate cathodes for each segment.

In our clock, the colons between the digits are formed from discrete 5mm LEDs which are chosen to have a similar colour and brightness to the digit segments.

Most 7-segment display data sheets lack good data on the LED characteristics, which is important to determine how best to drive them. We purchased a number of compatible 7-segment modules in various colours and tested them. Some of these came from long-established LED manufacturer Kingbright while others came from Chinese factories.

While it may seem surprising, overall we found the Chinese-sourced displays to give the best results, offering very high and even brightness at a reasonable price. We'll be offering some of these in our on-line shop for readers who wish to build a clock using these units.

The results of our measurements are shown in Fig.3. This shows the forward voltage of the four series LEDs in one segment from each display along with the current flow for that voltage. The dot on each curve shows the point at which we considered the light output to be subjectively bright and gives some idea of how hard each display type would have to be driven to achieve a sufficient brightness level.

The LBT23101BG curve has no dot because it did not achieve what we would consider to be a sufficient brightness level even at 100mA! These also showed a dramatic colour shift towards red at higher DC currents so we would not recommend these be used, especially for a multiplexed display like this one.

As expected, the blue LEDs have the highest forward voltage (a typical blue LED has a voltage drop of 3-3.6V) while the red LEDs have the lowest and thus would be suitable for use with a 12V supply such as in a car or caravan. Green and yellow LEDs tend to fall in-between. We didn't test white displays but we expect they would have similar characteristics to the blue types.

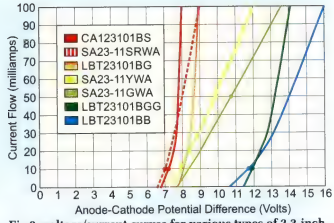
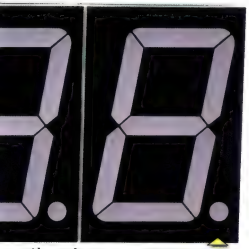


Fig.3: voltage/current curves for various types of 2.3-inch 7-segment LED displays. The SA23 types are from Kingbright while the others are from various Chinese LED factories. The dots on each curve indicate the current level at which high brightness is apparent. Note the dramatic colour shift with current of the LBT23101BG.

There were some surprises in the results. Of the green displays, the most expensive were the "emerald green" types and these have a colour more towards the blue end of the spectrum, while the standard green types are more yellow. As you can see, the emerald green LEDs have quite similar characteristics to the blue LEDs, with a high forward voltage, but they are also extremely bright even at low currents. This, combined with the pleasant shade of green and good colour consistently would make them our first choice for building a green LED clock.

Our conclusions are as follows: the Kingbright SA23-11SRWA and Chinese CA123101BS are similar and both quite suitable red displays. Kingbright SA23-11YWA (yellow) and SA23-11GWA (green) are usable but need to be driven right to their instantaneous current limits for sufficient brightness.

For colours other than red, the Chinese-sourced LBT-23101BGG (emerald green) and LBT23101BB (blue) look excellent however they also require a 15-18V supply to get a good and consistent brightness level.



Above: the 7-segment LED displays plug into sets of 5-way SIL sockets, as shown on Fig.2. Make sure that the displays are all correctly orientated (ie, decimal points at bottom right).

plus symbol on the PCB shows how it is orientated.

Infrared receiver IRD1 is mounted on the same side of the PCB as the other components installed so far, however it's flush against the PCB and "looks" through the adjacent hole. Bend its leads down very close to the body, towards the lens, but don't let them actually touch the body as it may be made of conductive plastic. Push it down so that the lens protrudes through the hole in the PCB as much as possible, then solder and trim the leads.

Assuming you are fitting a GPS module, attach it in the mounting location provided using doubled-sided tape, with the ceramic patch antenna at the top, and solder the four, five or six wires to the adjacent pads. Refer to Fig.2 to see which wires go where. All modules will need the GND, RX, TX and V+ wires connected. Modules with a 1PPS output should also have that wire connected and if the module requires a RAM back-up supply, connect it to the "VBAT" pad.

Place the jumper shunt on LK1 to select either the 3.3V or 5V supply as needed (if your module will run off both, use the 3.3V supply). **As mentioned earlier, if your GPS module uses RS-232 levels, you will need to solder a series resistor of around 6.8kΩ between the module and the TX pad on the PCB or IC1 could be damaged.**

We used an RS-232 EM408 module in our prototype so we soldered two resistors to CON2, one from +V to pull its enable pin high and one in series with the TX pin as mentioned above.

Next, plug IC1 into its socket. Make sure its orientation is correct. If your chip is not already programmed, you can connect a PICkit3 (or similar) to CON3, the ICSP header. Switch on the PICkit's internal 3.3V power supply and program the chip.

Alternatively, you could feed 12V DC into CON1; assuming the board has been built correctly, this should also allow you to program the chip.

Displays

The displays are not soldered to the PCB directly as this would block access to the solder joints for the remaining components, should one of them require replacement. Instead, they plug into socket strips. Snap or cut the socket strips into 12 lengths with five pins each. Do this carefully as the plastic surround can break off in the wrong place if you aren't careful. The overlay diagram for this side of the board is also shown in Fig.2.

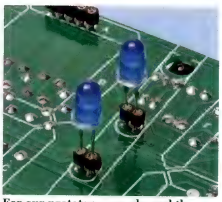
Solder these on the opposite side of the PCB to the other components, at the top and bottom of each display location. Make sure they are all pushed down fully into the PCB and line up properly. Now trim the leads of all the displays to 5mm and plug them in. The easiest way to ensure the displays sit at a consistent level is to cut a 5mm wide strip of cardboard and use this as a template while trimming the pins.

When plugged in, the back of each display should rest just above the top of the socket strips. Make sure the display orientation is correct, ie, the decimal points are all lined up along the bottom of the PCB.

Check that the distance from the front of the displays to the top of the tallest component on the other side of the board is no more than 30mm. If it's more than this, you will need to trim the display leads further. In practice, this means the top of each display should be just under 17mm from the PCB surface.

The LDR is located on the same side as the displays and fits between DISP2 and DISP3. Solder it a couple of millimetres above the surface of the PCB, just below the bottom edge of the displays.

The final components to install are the four LEDs which form the colons between the hours, minutes and seconds parts of the display (and flash at 1Hz). These are fitted so the domed parts of their lenses protrude above



For our prototype, we plugged the 5mm blue LEDs into short sections of socket strip cut from what was left after fashioning the sockets for the six digits. This makes it easier to try out different LEDs for the best colour match and viewing angle to go with the clock display.

the top of the displays.

This requires them to be mounted so that their plastic bodies are 11mm above the PCB. You can achieve this by placing an 11mm tall cardboard spacer between the leads and pushing the LED down so that bottom of its lens is in contact with the spacer. It's then just a matter of soldering and trimming the leads and sliding the spacer out. Make sure all four anodes (longer leads) are orientated towards the lefthand edge of the PCB as shown in Fig.2. Similarly, the flat sides of the LEDs should go to the right.

For our prototype, we trimmed the LED leads shorter and plugged them in using short pieces of socket strip, as shown in the above photo. This allowed us to easily experiment with several different types of LED to find a good match for the 7-segment displays.

If you're using LEDs that we've supplied with the 7-segment displays, you don't need to do this but if using other LED types, it might be a good idea.

Note that the LED mounting locations are slightly staggered, so that the "colons" they form line up with the slanted 7-segment digits. The 5mm LED lens domes protrude above the 7-segment displays so that they can be seen when the display is viewed at an angle; these poke through holes in the laser-cut case which hold them neatly in place despite the long leads.

That's all for this month. Next month, we'll go over testing the PCB, making the case, putting it all together and explain how to set up the remote control, set the time and use the various functions of the clock. SC

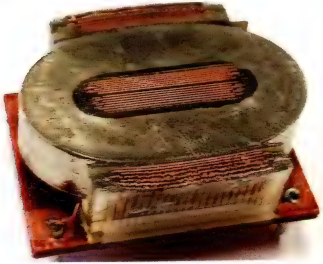
High-quality Audio Transformers from Sweden

Lundahl of Stockholm, Sweden have a reputation for quality in both the Pro Audio and "Audiophile" communities. Their unique manufacturing processes produce power, audio coupling, valve output, and audio/video isolation transformers with a high degree of consistency.

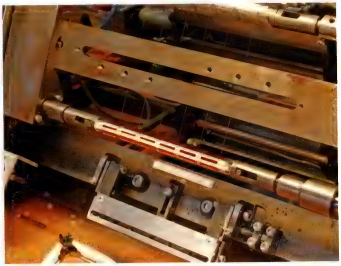
In the Pro Audio world, Lundahl make transformers for ground isolation, signal splitting, balanced/unbalanced conversion, microphones, mic preamps, line input and output, digital audio impedance matching/isolation/splitting, 100V PA work and even telephone systems. Their pro audio transformers are designed with a wide bandwidth and for minimal impact on audio quality.

In an interview, owner Per Lundahl told us that Lundahl isolation transformers are often provided in pro audio gear as an option for those serious about sound quality.

For equipment that comes with Lundahl transformers as standard, this is usually a sign that it was designed with ultimate audio quality in mind. It's also quite common for musicians to buy gear with cheaper transformers and

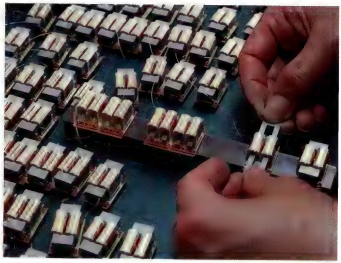


This cross-sectional view of a Lundahl signal transformer shows how the neat winding layers are each separated with insulating plastic. This is one of their wound amorphous cores.



One of Lundahls's bobbin-less winding jigs, producing six sets of windings simultaneously. After each coil layer is wound, another insulating layer is placed on top and then the winding continues.

Two of the finished winding assemblies have been attached to a baseboard and the windings are being terminated to it. There are many steps required to produce these transformers; some are automated or semi-automated.



C-cores are inserted thorugh the windings of the finished assemblies. Strip-wound amorphous cores as shown opposite are generally considered to give lower audio distortion but C-cores are also a common option.

swap them for a Lundahl equivalent as an easy upgrade.

According to Per, Lundahl transformers have a reputation for audible "transparency" – which we take to mean that they introduce very little distortion to the signal being passed through.

He said that one reason for this may be the fact that they are generally designed to pass a much wider range of frequencies than just the audio band, to minimise roll-off and distortion of audible signals near the upper or lower ends of the spectrum.

The consistency and performance of their pro audio transformers is in part due to the unique bobbin-less method of construction, a cross-sectional view shown below left. The second photo shows the winding rig which creates multiple sets simultaneously. After the tight-packed windings are wound on each insulation layer, a new insulating layer is placed on top and the next layer started. This results in low inter-winding capacitance and a high breakdown voltage.

The photo above left shows two of these now separated windings being wired to a series of pins on the baseplate after which the core is inserted. Two types of cores are used for these small transformers, either a pair of C-core halves as shown in the following photo or a single amorphous core as shown in the cut-away.

This type of construction seems physically impossible but the core is actually wound from a metal strip of amorphous material which passes through both already completed windings.

This is the preferred type of core for low-distortion audio applications. Whichever type of core is used, the assembly is then placed in a shielding can and impregnated with a plastic compound to resist moisture ingress.

Valve amplifier transformers

Lundahl also have an extensive range of transformer for valve amps and vinyl preamps including power supply transformers, output transformers, filter chokes, anode supply chokes and moving coil pickup input transformers. As with their pro audio transformers, the valve audio transformers have a reputation for clarity.

All their mains transformers are designed to work from either 105-125VAC or 210-250VAC mains. There are thirteen different types, providing a range of different HT voltages (from 110VAC up to 530-0-530VAC) and filament or low voltage supplies; typically this includes two or more ~6V windings and in some cases an extra 48VAC winding (eg, for microphone phantom power).

Lundahl offer a large range of output transformers – more than fifty types, to suit various different output impedances ranging from 600Ω up to 23kΩ and secondary (speaker) impedances of four, eight or 16 ohms. Power ratings range from 5W up to 320W! (30Hz, push-pull.)

For a complete list of Lundahl output transformers, see the URL at the end of this article.

We're particularly happy to note that full PDF data for all their transformers is available at their main site (**www.lundahl.se**).

This includes physical dimensions (including numbered pins), along with a diagram showing all the windings, their pin connections and orientations, turns ratios, winding resistances and impedances, maximum recommended DC current, maximum signal voltage and power, inductance etc.

In short, they provide a very comprehensive set of data, exactly what you need to design a project around the transformer and ensure that it's the best one for the job.

They even provide suggestions for the various different configurations in which the transformer could be used in the relevant data sheet. Browsing the various data sheets is an excellent way to shop for the appropriate transformer for your next project.

Australian Distributors

The Australia and New Zealand distributors for Lundahl transformers are CDA Pro Audio, a "sister company" to Control Devices. They have offices in Sydney, Perth and Auckland.

For more information contact their Audio Products Manager, Peter Orehov on (02) 9330 1750; (e-mail **info@cda-proaudio.com**). A list of available Lundahl transformers can be viewed at **www.cda-proaudio.com/Subcategorie/Transformers_products.html**

PRODUCT SHOWCASE

PowerTran High Power USB supply/charger from Altronics

With so many devices now operating or being re-charged by USB ports, you're almost certain to run out of options one day. This 120/240V desktop charger from Altronics not only charges up to 5 device at once, it uses a new technology called "Charge IQ" to allow the unit to charge a connected device at the fastest possible speed. It identifies the device and delivers the maximum power to charge the device in the shortest time possible. This generally applies to iPhones after generation 4, iPads after generation 3, the Samsung Galaxy range of phones and tablets and the HTC One (M8/M7). It is expected that many newer devices coming onto the market will also have Charge IQ capability.

The 73 x 73 x 34mm charger (Cat M-8880) has over-current, over-voltage, over-temperature and overload protection. Charging rate can be up to 7.8A (@5V). A standard 3-pin, 230V power cord is included – no USB cables are supplied as it is assumed any USB device will have its own cable. (USB charging ports are standard female type A). Price is $49.95

Contact:
Altronics
(All stores and resellers)
Tel: (1300) 797 007
Web: www.altronics.com.au

New Hafco WoodMaster Band Saws

If you're in the market for a new band saw to cut your timber for the workshop, Hare & Forbes Machineryhouse have just introduced three new Woodmaster models. The range includes a 255mm 0.5hp, 310mm 1hp and 360mm 1.5hp and only require 230 V single phase power. All include a generous cast iron work table that can tilt to 45° to minimise flex when cutting heavier timbers and are nicely finished with curved blade guards.

The sturdy fabricated steel saw frame and stand provides plenty of rigidity throughout the machine. They're fitted with a LED light on a flexible arm, ball-bearing blade guides, safety magnetic switch and emergency stop for additional user protection, rear dust collector port, slide-out dust drawer for collecting more dust and as well as two blade speeds, perfect for cutting a wide range of timbers. An optional circle cutting attachment fits directly onto the adjustable top blade guide for further versatility.

These band saws are packed full of essential features great for every wood worker and have a starting price of $451.

Contact:
Hare&Forbes Machineryhouse
Sydney, Melbourne, Brisbane, Perth
Tel: [Sydney] (02) 9890 9111
Web: www.machineryhouse.com.au

Two new Christmas presents (for yourself?) from Tecsun Radios Australia

Two of the most popular portable receivers in the Tecsun range have just had major makeover, making them even better value for money.

Tecsun PL-680

It looks very similar to the PL660 but has been upgraded in several key performance areas, all of which make listening even more pleasurable: • Improved sensitivity • Improved synchronous detection • No soft muting • Measured AM performance identical (even though specs suggest slightly inferior!).

The radio features PLL synthesis and can tune the AM and FM broadcast bands, SW from DC to Daylight (OK, 1171kHz to 29.9999MHz), longwave from 100-519kHz and, somewhat unusually in a portable radio, the entire aircraft band from 118 to 137MHz. With 2000 memory presets, you're never going to forget that elusive station again!

While the PL680 can be used with four standard AA alkaline batteries, it will also accept NiMH cells, which can be charged via the fitted USB socket. A quality leatherette carry case, ear buds and other accessories are included.

For keen shortwave listeners, you'll notice the difference in the PL-680. Price is $199.00

Tecsun PL-365

"In the shirt pocket" style receiver, similar to the PL-360 but with updated specs and performance.

It's a DSP receiver, which means it has digital signal processing to greatly enhance the radio's sensitivity, selectivity, signal-to-noise ratio and anti-interference. It covers the AM and FM broadcast bands and shortwave from 1171kHz to 29.9999MHz.

One of the things that Tecsun Radios Australia report from customers is that they really like the "long, thin" style which easily slips into a shirt pocket. Like its predecessor, it measures just 159 x 53 x 26mm.

It too takes either alkaline AA batteries or NiMH rechargeables (in this case three), with the latter rechargeable via the USB port (either a dedicated charger or the USB port on your PC).

A "wetsuit"-type pouch is included for protection (note that it is DEFINITELY not waterproof!).

Also included are a pair of ear buds plus two antennas – a high-sensitivity plug-in AM type which slots into a socket on the top of the radio and a long-wire antenna which clips onto the PL-365's whip antenna. Price for the PL-365 is $89.00

Contact:
Tecsun Radios Australia
24/9 Powells Road, Brookvale NSW 2100
Tel: (02) 9939 4377
Web: www.tecsunradios.com.au

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- Relative measurement
- Case included
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- 220m Dia. Print area
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ARDUINO® - MORE ARDUINO® PRODUCTS ON PAGE 7

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Full featured MP3 module that supports playback and recording. It comes with a microphone used for audio in and with a line-in header to use a different external audio source. A 3.5mm jack provides the output.

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This remarkably small module provides a complete 2 x 3W stereo audio amplifier. Ideal for driving small speakers and earphones. Requires no external components.

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Most projects using this device will require some form of mass-storage, such as an SD card.

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- HDMI 1.4
- IR remote control for switching sources supplied
- Dimensions: 65(W) x 192(D) x 26(H)mm

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** Depending on cable used and resolution. See website for details.*

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- HDMI 1.4

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HDMI Infrared Extender
AC-1744

A simple and discrete way to remotely control a cable/satellite receiver, DVD player, or other home theater source. Kit includes HDMI Adapter, IR transmitter and emitter pigtail with 1.5m length of cable. 1080p 3D ready. No external power supply required.

DOUBLE POINTS

$59.95

4 Channel Compact Infrared Extender Kit AR-1828

Control Blu-Ray players, set-top boxes, and other home theatre/audio equipment even if they're hidden behind cabinet walls or other types of enclosures. 2 x Dual IR emitter cables included.

See website for full contents.

4K UHD

15% OFF 1.5M HDMI 2.0 CABLES FOR NERD PERKS CARD HOLDERS*
WQ-7900

WQ-7900 VALUED AT $29.95

FROM $79.95

AC-1768

HDMI 2.0 UHD Splitters
Split a single HDMI input to multiple HDMI outputs. Support all 3D TV formats in addition to all HDTV formats up to 4K UHD. Support smart auto switch.

2 OUTPUTS AC-1766 **$79.95**

4 OUTPUTS AC-1768 **$129**

WALLPLATES

Brush Cable Entry Wall Plate PS-0291
Single gang brush plate for cable entry through walls etc. Suitable for pre terminated cables going to LCD or plasma screens, and particularly suited to HDMI cables as they can't be split, spliced or field-terminated.

ALSO AVAILABLE:

BRUSHED REAR CABLE ENTRY WALL PLATE PS-0296 **$9.95**

$9.95

HDMI Wall Plate WITH FLYLEAD
PS-0281

$14.95

Standard Australian/NZ GPO mount with HDMI sockets for AV installations. Comes with a single or dual HDMI port with flexible flylead for better inner wall clearance.

$24.95

Wallplate with VGA, PC Audio, and Composite AV PT-0471
Multimedia Wallplate with VGA, PC Audio, and Composite AV
- Standard GPO mount wallplate with concealed screws
- Approximate cavity depth required 60mm
- Plate dimensions 116(H) x 75(W) x 12(D)mm

Limited stock.

AUDIO

DOUBLE POINTS ON THESE CABLES FOR NERD PERKS CARD HOLDERS See page 8 for list of products.

Best Quality Audio & Visual Leads

FROM $4.50

STEREO TO RCA LEADS:

3.5MM STEREO PLUG TO 2XRCA PLUGS - 1.5M
WQ-7206 **$17.95**

3.5MM STEREO PLUG TO 2XRCA PLUGS - 3M
WQ-7208 **$18.95**

RCA TO RCA LEADS:

2 X RCA PLUGS TO 2 X RCA PLUGS - 0.5M
WQ-7227 **$16.95**

2 X RCA PLUGS TO 2 X RCA PLUGS - 1.5M
WQ-7226 **$18.95**

2 X RCA PLUGS TO 2 X RCA PLUGS HQ - 3M
WQ-7228 **$24.95**

2 X RCA PLUGS TO 2 X RCA PLUGS - 5M
WQ-7230 **$29.95**

2 X RCA PLUGS TO 2 X RCA PLUGS HQ - 10M
WQ-7232 **$49.95**

Best Quality Audio Leads

3.5MM STEREO PLUG TO 3.5MM STEREO PLUG - 0.5M
WA-7007 **$4.50**

3.5MM STEREO PLUG TO 3.5MM STEREO PLUG - 1.5M
WA-7008 **$4.95**

3.5MM STEREO PLUG TO 2 X RCA PLUGS - 1.5M
WA-7014 **$6.50**

WA-7007

SPEAKER CABLES - NERD PERKS OFFER

bulk roll discounts for selected cables, join now and ask us how.

FROM $1.20/m

Speaker Cables

HEAVY DUTY WB-1708 **$1.20/M**
Suited for speaker systems above 150 watts, 19 x 0.18mm. Black with white trace.

JUMBO WB-1732 **$4.10/M**
For those who want top quality jumbo speaker cable. 259 0.12mm strands in each side.

PRO AUDIO WB-1754 **$1.70/M**
Super flexible speaker cable. Separate colour-coded 18AWG red and black conductors in a single outer sheath.

FREE 30M HEAVY DUTY SPEAKER CABLE* WB-1709
*WB-1709 VALUED AT $23.95

Indoor/Outdoor Speaker Systems

- 2-way speaker systems with polypropylene woofer and dome tweeter
- 180 degrees rotatable for perfect sound projection
- Can be mounted to a wall or ceiling
- Sold as a pair

4.0" SPEAKERS CS-2475 **$69.95**
6.5" SPEAKERS CS-2477 **$119**
8.0" SPEAKERS CS-2478 **$189**

FROM $69.95

CS-2475

CEILING SPEAKERS

FREE 30M HEAVY DUTY SPEAKER CABLE WB-1709
*WB-1709 VALUED AT $23.95

NEW

FROM $59.95

CS-2451

In-Ceiling 2 Way Speakers

A great alternative to having bulky traditional PA speakers cluttering the home theatre, entertaining space or office. Flush mount design and fold out retaining clamps for easy installation. 8 ohm impedance. Sold as a pair.

5.25" 25WRMS FIXED TWEETER CS-2451 **$59.95**
6.5" 30WRMS SWIVEL TWEETER CS-2453 **$79.95**
8" 40WRMS SWIVEL TWEETER CS-2455 **$99.95**

$349

6.5" 2 Way Ceiling Wi-Fi Speakers

CS-2468

- Built-in Wi-Fi function; can be controlled by Smartphone/Tablet/PC
- Built-in Hi-Fi level amplifier: 2 channel 2 x 50WRMS
- Multi room functionality

TWEETERS AND WOOFERS

$19.95

25mm Titanium Dome Tweeter

CT-2007
This tweeter features a titanium dome with a phase shield which provides a more controlled high frequency roll-off. It produces very crisp and clear high frequencies.

- Power nominal: 50WRMS
- Nominal impedance: 8 ohms
- Frequency response: 2-20kHz
- Sensitivity: 91dB (1W at 1m)

FREE 1M ACRYLIC SPEAKER DAMPENING MATERIAL* AX-3694
*AX-3694 VALUED AT $12.50

FROM $39.95

CW-2198

Paper Cone Woofers

Excellent for replacement or for new speaker design constructions. Specifications:

8" 90 WRMS CW-2196 **$39.95**
10" 225 WRMS CW-2198 **$59.95**
12" 225 WRMS CW-2199 **$79.95**

BUILD YOUR OWN SPEAKER CABLE

ALL THE TOOLS YOU NEED IN ONE GREAT VALUE BUNDLE PRICE!

BUY ALL 4 FOR $39.95
SAVE OVER $19

$1.95

0.71mm Duratech Solder - Hobby Pack NS-3008

- Solder 60% tin / 40% Lead
- Resin core
- Supplied in easy to use cannister
- Contains 15 -20g weight

Heavy Duty Speaker Cable - 30mt Roll WB-1709

- 24/0.20mm Figure 8 with trace
- Roll length 30 metres

$23.95

$15.95

Stainless Steel Wire Stripper / Cutter / Pliers TH-1841

- High quality precision wire stripper, cutter and plier with loop hole
- Strips stranded wire from 12-24 AWG and solid wire from 10-22 AWG
- Will also cut steel wires up to 3.0mm
- Spring-loaded with locking jaws
- 164mm long

$17.95

20/130W Turbo Soldering Iron

TS-1554
This turbo soldering iron allows you to switch from 20W to 130W with ease. Weller-style removable barrel, plated tip and ceramic element.

DOUBLE POINTS FOR NERD PERKS CARD HOLDERS ON THESE AMPLIFIERS

*Valid for purchase of AA-0488, AA-0477, AA-0479 or AA-0505

DOUBLE POINTS

2 x 50 WRMS Compact Stereo PA Amplifier
AA-0488
$169

Uses digital sound processing to deliver the quality of a Class AB amplifier with the efficiency of a Class D. Solid aluminium body, banana socket speaker terminals, stereo RCA audio input, front panel 3.5mm stereo input & 6.5mm headphone socket.
- Includes power supply and audio cables.

DOUBLE POINTS

2 X 75 WRMS Compact Stereo Amplifier
AA-0505
$219

This is an unbelievable product.
- A powerful 2 Channel (Stereo) and such a compact size.
- Built-in digital signal processor
- Includes power supply and audio cables.
- 165(L) x 95(L) x 30(H)mm

DOUBLE POINTS

Dual Channel / Bridged Rack Mount Amplifiers
FROM $269

Very cost-effective solution for a pro audio application. Can be run as dual channel, stereo or bridged. Solid aluminium chassis and front panels.

200 WRMS BRIDGED AA-0477 **$269**

400 WRMS BRIDGED AA-0479 **$379**

TOOLS AND ACCESSORIES

DOUBLE POINTS

Fujiya Precision Side Cutters
TH-2332
$29.95

Precision ground and perfect for cutting super fine wire as well as for general workshop use. The insulated soft grip handles are spring loaded for effortless use. 110mm long.

DOUBLE POINTS

ESD Safe Sidecutters
TH-1922
$32.95

Specifically for ESD work. High quality Japanese designed, Italian manufactured cutters especially for static-sensitive applications. 135mm long.

DOUBLE POINTS

Pro Sound Level Meter WITH CALIBRATOR
QM-1592
$349

- Scales for A and C weighting.
- Ideal for vehicle, traffic or any evidence-based noise testing.
- Range: 30 to 130dB (±1.4dB)

Cat III 2000 Count Inductance / Capacitance DMM QM-1548

Wide range of inductance and capacitance measurement. Large LCD. Includes quality test leads.
- 600V
- 10A AC/DC current
- Hfe transistor test
- Auto power off
- Data hold

$49.95 DOUBLE POINTS

True RMS Autoranging Cat IV DMM
QM-1571
$109

- Impact resistant and quite durable
- IP67 waterproof rating
- Non-contact voltage
- Data hold
- Diode test
- Autoranging
- 10A current range

DOUBLE POINTS

True RMS Cat IV DMM WITH METERBOX SMARTPHONE APP
QM-1576
$229

- IP 67 waterproof rating
- Digitech DMM Smartphone app
- Bluetooth® Smartphone/PC interface
- Data hold/Min/Max recording
- 10A current range
- Autoranging

DOUBLE POINTS

AUDIO CONVERTERS

FREE TOSLINK CABLE FOR NERD PERKS CARD HOLDERS* WQ-7301

WQ-7301 VALUED AT $15.95

HD Audio Digital to Analogue Converter AC-1631
$64.95

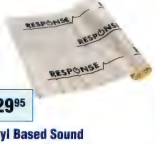
Compact converter takes a digital optical or coaxial input and converts it to standard analogue left and right stereo audio.

AC3/DTS Digital Audio to Analogue Converter AC-1658
$99.95

Convert digital audio sources that use Dolby Digital AC3 Pro logic, DTS, PCM or other formats into 2.0 channel analogue audio output. A convenient turnkey solution for audio connectivity differences.

Electronic Cleaning Solvent Spray Can NA-1004
$11.50

- Non CFC ozone free propellant
- Highly efficient fast drying solvent of high purity
- Suitable on delicate electronic, electrical & precision mechanical assemblies



Butyl Based Sound Deadening Material
AX-3687
$29.95

Give your vibrating buzz-box a luxury car ride with this butyl-based, foil backed sound deadening material. Self-adhesive and easily moulded.

Thickness: 1.5mm
Size: 900 x 330mm

22 Piece Long Bit Screwdriver Set WITH CASE
TD-2114
$34.95

Tackle a wide range of fastening scenarios using our compact screwdriver set comprised of a selection of popular slotted, Phillips, Star and TRI bits, packed away neatly inside a handy storage case. *See website for contents*

Turntable Preamp Switch Box AC-1662
$24.95

Many modern amplifiers no longer have a phono input for turntables. This preamplifier overcomes the problem and provides two selectable inputs to a stereo line level output for your stereo amplifier. Requires 9V DC adaptor.
- 160(L) x 100(D) x 40 (H)mm

Limited stock

DOUBLE POINTS FOR NERD PERKS CARD HOLDERS ON ANTENNAS & ACCESSORIES

Valid with purchase of LT-3130,LT-3181, LT-3182,LT-3143,LT-3137, LT-3202, LT-3084, LT-3332, WV-7451, WV-7452, WV-7454, WV-7456, WV-7350, WV-7914, WB-2014, TH-2000 or TH-1820

TV Mounting Brackets

Don't pay too much for quality mounting brackets. We have a HUGE range of high quality brackets to suit virtually all TV screens.

ULTRA SLIM TILTING WALL MOUNT:

23-55" 25KG CW-2836 **$39.95**

40-65" 25KG CW-2838 **$49.95**

ULTRA SLIM ARTICULATING WALL MOUNT:

32-55" 25KG 180° SWIVEL CW-2852

WAS $119 NOW $99 SAVE $20

PLASMA/LCD TV WALL BRACKET:

23-37" 45KG ANTI-THEFT LOCK CW-2826

WAS $39.95 NOW $34.95 SAVE $5

32-60" 80KG ANTI-THEFT LOCK CW-2822

WAS $89.95 NOW $79.95 SAVE $10

PLASMA TV WALL BRACKET:

32-60" 80KG 180° SWIVEL SLIM CW-2825

WAS $149 NOW $129 SAVE $20

CEILING MOUNT 32-60" 80KG CW-2855

WAS $169 NOW $139 SAVE $30

See website for details. Limited stock.

FROM **$34.95**

SAVE UP TO $30

UHF Antennas

TV antennas suitable for medium or deep fringe signal reception areas. Both feature an LTE filter to prevent interference from 4G/LTE mobile networks, which is housed within a waterproof dipole box with F-type connection.

43 ELEMENT LT-3181 **$44.95**

91 ELEMENT LT-3182 **$89.95**

FROM **$44.95**

DOUBLE POINTS

UHF Phased Array TV Antenna

RECEIVES BANDS 4 AND 5

LT-3138 **WAS $74.95**

Suits analogue or digital TV and ideal for fringe areas, where ghosting is a problem.

- UHF channels - 21 to 69 (27 to 62 in NZ)
- Size: 610 x 890mm

NOW **$64.95**

SAVE $10

DOUBLE POINTS

$59.95

DOUBLE POINTS

Outdoor UHF/VHF/Marine TV Antenna

WITH ROTATION MOTOR LT-3143

It includes a signal amplifier (240VAC adaptor supplied) AND a rotator motor built into the antenna housing AND a remote control for that. It also comes with approx. 8 metres of TV lead with a weatherproof plug on one end.

$99.95

DOUBLE POINTS

UHF/VHF Digital Antenna LT-3137

This versatile unit provides you with high quality clear digital reception with minimal footprint. The panel can be mounted to the wall, or clamped to a pole. Power supply included.

- VHF frequency: 174-230MHz
- UHF frequency: 470-862MHz
- Size: 502(L) x 235(W) x 76(H)mm

VIDEO / TV LEADS AND COAXIAL CABLE

$5.95

DOUBLE POINTS

TV Coaxial Plug to TV Coaxial Plug Cable - 1.5m

WV-7350

RG- 59U coaxial cable. Double shielded cable.

$9.95

DOUBLE POINTS

Bargain HDMI Lead 1.5m

WV-7914

HDMI Standard with Ethernet. Made from 99.99% pure copper, with triple layer shielding and nickel plated connectors. Supports 1080p.

FLEXIBLE COAXIAL LEADS

FROM **$19.95**

Great for long cable runs. Flexible. Prevent tangling/kinking. F Plug to F Plug. Blue colour.

RG59 10M WV-7450 **$19.95**

RG59 20M WV-7452 **$29.95**

RG6 10M WV-7454 **$29.95**

RG6 20M WV-7456 **$39.95**

DOUBLE POINTS

$45.95

DOUBLE POINTS

TV Coaxial Cable

WB-2014

Great for domestic TV & Pay TV installations! 75 ohm RG6 quad shield coax in a handy 30m roll.

TV ANTENNA ACCESSORIES

DOUBLE POINTS

FROM **$24.95**

Indoor Amplifiers/Splitters LT-3282

Split and amplify UHF, VHF or FM signals to 4 or 2 other units with these handy amplifier splitters. Features high gain and low noise to ensure the signal is of a high quality.

2 WAY INDOOR AMPLIFIER/SPLITTER LT-3282 **$24.95**

4 WAY INDOOR AMPLIFIER/SPLITTER LT-3284 **$34.95**

DOUBLE POINTS

$39.95

Digital TV Signal Strength Meter

LT-3332

Connect the pocket sized DVB-T signal strength meter and adjust the angle of your digital TV antenna, the easy to read LED indicator lets you know when you've hit the right spot. Adapters included.

- Requires 1 x 9V battery (sold separately)
- Frequency range: 40-862MHz

TV AND VIDEO TOOLS

$19.95

DOUBLE POINTS

Rotary Coax Stripper

TH-1820

Handy stripper that will strip the outside jacket and inner conductor in one operation. Simply rotate the stripper clockwise around the cable 3 to 6 times. A quality stripper suited to installers. Suitable for RG58/59/62/6 and 3C2V 75 ohm cable

Limited stock.

FREE QUICK CHANGE CRIMP TOOL DIES FOR NERD PERKS CARD HOLDERS* TH-2005

TH-2005 VALUED AT $17.95

$49.95

DOUBLE POINTS

Heavy Duty Crimp Tool

TH-2000

Heavy duty and ergonomic crimper that uses quick interchangeable dies, no screwdriver needed. Features ratchet mechanism for maximum power and quick release.

ARDUINO® COMPATIBLE

$89.95

Arduino® Experimenters Kit
XC-4262
Learn about the exciting new world of Arduino with these easy to build projects. From flashing an LED to moving things with a servo. Complete with instructions, supporting web page & software examples.
- No soldering required

NERD PERKS OFFER
BUY BOTH FOR $243
SAVE $15

PcDuino V3.0
WITH WI-FI XC-4350 **$119**
pcDuino V3.0 is a high performance, cost effective mini PC platform that runs on Ubuntu or Android ICS. With onboard HDMI, USB, SATA, LVDS and Wi-Fi you can use it in robotics, home theatre, electronic control and other various applications.

ALSO AVAILABLE:
7" 1024 X 600 LCD TOUCHSCREEN XC-4356 **$139**

EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 JAYCOINS CARD ONCE YOU REACH 500 POINTS!
Conditions apply. See website for T&Cs

SIGN-UP IN-STORE OR ONLINE TODAY BY VISITING:
www.jaycar.com.au/nerdperks

ARDUINO® COMPATIBLE SHIELDS AND MODULES

duinotech

NEW

$12.95

Arduino® Compatible Prototyping Shield XC-4482
This stackable shield makes semi-permanent prototyping simple.
- Includes reset button.
- SOIC-14 breakout, for surface mount ICs
- Dimensions: 68(L) x 53(W) x 12(H)mm

NEW

$19.95

Arduino® Compatible Data Logging Shield XC-4536
Store your data to files on any FAT16 or FAT32 formatted SD card, or have it to be read by any plotting, spreadsheet or analysis program.
- 102 solder pads
- Changeable CR1220 battery
- Dimensions: 43(L) x 17(W) x 9(H)mm

$29.95

433MHz Receiver Shield
FOR ARDUINO® XC-4220
Lets you intercept 433MHz OOK/ASK signals, decoding them in software on your Arduino®
- Reset button
- 433.92MHz tuned frequency

NEW

$39.95

Arduino® Compatible USB Host Expansion Board XC-4456
Brings the ubiquitous USB Host connectivity to your Arduino® project. Supports Google Android® ADK allowing connections to Smartphones and Tablets.
- Dimensions: 55(W) x 54(D) x 23(H)mm

NEW

$3.95

Arduino® Compatible Infrared TX module XC-4426
Use your Arduino® to control your TV or Media Centre via Infrared. You could use it to control one of our Infrared RC helicopters!
- Operating Voltage: 5VDC

NEW

$3.95

Active Buzzer Module XC-4424
Use this module to generate sound from your Arduino®. Libraries available for different tones & frequencies.
- Operating voltage 5VDC
- Active speaker
- 3 pin header
- Dimensions: 25(L) x 15(W) 10(H)mm

NEW

$14.95

Arduino® Compatible Ethernet Interface Module XC-4436
Contains all the circuitry required to implement a complete Ethernet interface. Use this with your latest Duinotech project to send and receive e-mail or host it's on website!
- 160(L) x 60(D) x 15(H)mm

NEW

$19.95

Arduino® Compatible RF Transceiver Module XC-4522
Adds a versatile 433MHz radio to your Duinotech project allowing two-way wireless communication between Duinotechs. Controlled via SPI. Prewritten libraries available. Includes antenna.
- 32(W) x 19(L) x 19(H)mm (Excluding antenna)

NEW

$7.95

Arduino® Compatible Microphone Sound Sensor Module XC-4438
Highly sensitive with added advantage of two outputs. An analogue output for real time microphone voltage signal, and digital output. Great to turn your Arduino® into a voice recorder or vox.
- 5VDC operational voltage
- Sensitivity potentiometer adjustment
- Dimensions: 43(L) x 16(W) x 13(H)mm

NEW

$9.95

3W LED Module
XC-4468
High brightness LED in an easy to use modular package. Includes a PWM input for brightness control.
- Operating Voltage: 5VDC
- Colour Temperature: 6000K
- 30(L) x 23(W) x 6(H)mm

NEW

$12.95

Prototyping shield
FOR DUINOTECH – MEGA XC-4416
This shield gives you plenty of room to prototype your latest MEGA project. The stackable shield provides access to all of the MEGAs pins and plenty of solder pads to prototype on. A small solder-less breadboard is included for fast prototyping.
- Dimensions: 106(W) x 56(L) x 19(H)mm

NEW

$19.95

8 x 8 Dot Matrix Driver Module XC-4532
Driven by shift registers it requires only three inputs, plus power.
- Operating Voltage: 5VDC
- Daisy-chainable.
- Chipset: 74HC595
- Dimensions: 72(L) x 69(W) x 12(H)mm

PARTY SEASON

SIGHT AND SOUND BUNDLE

Add some sound & colour to your next party or event with this great value and complete bundle that we put together for you. It includes a speaker with stand, a super bright PAR light and all the relevant cables and plugs. Just add music !!!

$499

SAVE OVER $75

VALUED OVER $574

BUNDLE DEAL INCLUDES:

PORTABLE 15" PA SPEAKER WITH MP3 AND BLUETOOTH CS-2486 **$369**

ADJUSTABLE SPEAKER TRIPOD STAND CS-2864 **$119**

18 X 1W RGB LED PAR STAGE LIGHT ST-3600 **$74.95**

3 PIN XLR TYPE EXTENSION CABLES - 2M WA-7041 **$11.95**

DOUBLE POINTS FOR NERD PERKS CARD HOLDERS

9W Galaxy Magic LED Light

WITH DMX SL-3484

NEW

DOUBLE POINTS

Ideal for stage lighting, club and party applications.

- A moving stage light with 9 different colour combinations and effects.
- Select between automated colour patterns, sound activator or DMX controlled
- Power supply (100-240V) and remote included.

$79.95

7 x 4W RGB LED Stage Light

ST-3602

Stage DMX LED PAR Lights

- 7 x 4W RGBW LEDs
- Controls: sound, remote, DMX512
- Mains powered
- Size: 175(L) x 175(H) x 105(D)mm

DOUBLE POINTS

$119

900W DMX Fog Machine

AF-1213

Hook up to a DMX512 controller for total customisation of stage/ party effects. Fog can burst with the beats or wait at certain intervals and durations.

- Remote included
- Size: 335(L) x 150(W) x 186(H)mm

DOUBLE POINTS

ALSO AVAILABLE:

SPARE FOG JUICE 1 LITRE AF-1212 **$17.95**

$149

DMX Powered Laser Beam

SL-3451

Create lasers at your next party, concert, or stage production. This model features an XLR out plug that allows you to daisy-chain multiple units together for full DMX controlled ambience.

- Laser colours: Red, Green & Yellow
- Sound control: Auto, DMX-512 (7 channels)
- Mains powered
- Size: 363(L) x 143(W) x 67(H)mm

DOUBLE POINTS

$229

TERMS AND CONDITIONS: REWARDS / NERD PERKS CARD HOLDERS FREE GIFT, % SAVING DEALS, DOUBLE POINTS & MEMBERS OFFERS redeem **ACTIVE** Jaycar Rewards / Nerd Perks Card members at a store, by phone, via website for Rewards/ Nerd Perks Card T&Cs. **ON PAGE 1:** get a 15% off of WQ-7000 with purchase of either AC-1760 or AC-1762; **ON PAGE 3:** save $20 on AR-1671; get a 15% off of WQ-7000 with purchase of either AC-1760 or AC-1798; **ON PAGE 4:** get WB-1703 with a purchase of CS-3478, CP-2477, CS-2453 or CS-2455. Special price for the combined purchase of WB-1703, TH-1941, AC-3003 and TD-1554; Free AA-3594 with the combined purchase of CW-2907 and CW-2105. Double points with purchases made with WA-7221, WA-7228, WA-7229, WA-7232, WA-7307, WA-7308 and WA-7314. **ON PAGE 5:** for Nerd Perks card holders, get WQ-7301 with a purchase of AC-1651 or AC-1668. **ON PAGE 6:** for Nerd Perks card holders, get a TH-0986 with a purchase of TH-0900. Special price for the combined purchase of OM-2868, OM-2869, OM-2827, OM-2825, OM-2865, LT-3138. **ON PAGE 7:** NP members - with a combined purchase of AC-4650 and AC-4656 get a $15 discount. **ON PAGE 8:** Special price for the combined purchase of CS-2486, CS-2864, ST-3600 and WA-7041. **DOUBLE POINTS ACCRUED DURING THE PROMOTION PERIOD WILL BE ALLOCATED TO THE NERD PERKS CARD AFTER THE END OF THE PROMOTION. DOUBLE POINTS ACCRUED DURING THE PROMOTION PERIOD** will be allocated to the Nerd Perks card after the end of the promotion

Australian Capital Territory

Belconnen	Ph (02) 6253 5700
Fyshwick	Ph (02) 6238 1801
Tuggeranong	Ph (02) 6293 3270

New South Wales

Albury	Ph (02) 6021 6788
Alexandria	Ph (02) 9699 4699
Bankstown	Ph (02) 9709 2822
Blacktown	Ph (02) 9672 8400
Bondi Junction	Ph (02) 9369 3899
Brookvale	Ph (02) 9905 4130
Campbelltown	Ph (02) 4625 0775
Castle Hill	Ph (02) 9634 4470
Coffs Harbour	Ph (02) 6651 5238
Croydon	Ph (02) 9798 0402
Dubbo	Ph (02) 6881 8778
Erina	Ph (02) 4365 5433
Gore Hill	Ph (02) 9439 4799
Hornsby	Ph (02) 9476 8021
Maitland	Ph (02) 4934 4911
Mona Vale	Ph (02) 9979 1711
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Port Macquarie	Ph (02) 6581 4476
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Shellharbour	Ph (02) 4256 5106
Smithfield	Ph (02) 9604 7411
Sydney City	Ph (02) 9267 1614
Taren Point	Ph (02) 9531 7033
Tuggerah	Ph (02) 4353 5016
Tweed Heads	Ph (07) 5524 6566
Wagga Wagga	Ph (02) 6931 0033
Warriews Bay	Ph (02) 9913 8100
Warwick Farm	Ph (02) 9821 3100
Wollongong	Ph (02) 4225 0969

Queensland

Aspley	Ph (07) 3863 0099
Browns Plains	Ph (07) 3800 0877
Caboolture	Ph (07) 5432 3152
Cairns	Ph (07) 4041 0747
Calounda	Ph (07) 5491 1000
Capalaba	Ph (07) 3245 2014
Ipswich	Ph (07) 3282 5800
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SERVICEMAN'S LOG

The security tag on the champers

Dave Thompson*

Ever tried to remove a security tag that had inadvertently been left on a champagne bottle? The clever way, that is? Yours truly did recently before eventually admitting defeat and reaching for a Dremel. Also this month, two errant cats gave me a couple of paying (if unpleasant) jobs.

Items Covered This Month

- Dave's security tag challenge plus more cat problems
- Resurrecting fan IR remote controls
- Whirlpool dishwasher repair

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An interesting thing happened the other day that I thought I'd share with you. Every Christmas, I give my wife a bottle of her favourite champagne. At some point during the following year, she finds an excuse to break it out and, usually with friends or work colleagues, enjoys this annual treat.

This particular champers comes in a bottle (obviously) which is packed into a glossy cardboard presentation carton. This is relevant, so please bear with me.

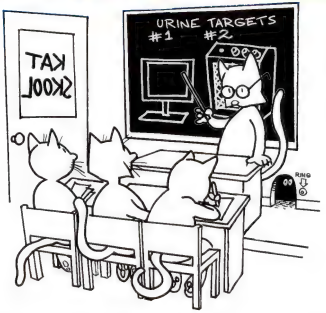
The other day, my wife had planned a get-together with an old friend and sought out the bubbly to take along. She quickly found it and asked me to put it in the fridge but when I opened the box, I discovered that one of those supermarket-type security tags was still fixed to the neck of the bottle. I've seen these tags before on high-end wines and beverages but the curious thing was that when I bought this from our local supermarket, I don't recall any embarrassing bleeps as I left the store (a supermarket? – I know, I know, but they do sell some very fancy grog and often at more competitive prices than those la-de-da posh outlets).

Like many people, I've had (on more than one occasion) a security tag trigger an alarm as I've left a store because a shop assistant has forgotten to disarm it. I tend to remember such instances because the noise usually results in store staff rushing all over the place and other customers jostling for the best position to witness the (alleged) shoplifter being shaken down and, with a bit of luck, tasered and publicly shamed. It's a case of guilty until proven innocent.

Anyway I digress; this security tag presented a problem. Drinkies was in about an hour and I had to get this thing off the bottle so that they would be able to open it. This type of tag is designed to be an obvious theft deterrent without totally destroying the shelf appeal of the bottle. It consists of what looks like a clear plastic cup that sits inverted over the cork and disappears into a moulded-plastic ring that fits around the neck a few centimetres below. It also uses some kind of contracting ring which is intended to make removal impossible without the proper tool.

~TO WITNESS THE (ALLEGED) SHOPLIFTER BEING SHAKEN DOWN AND, WITH A BIT OF LUCK, TASERED & PUBLICLY SHAMED...

I did what anyone else would do in the circumstances and turned to my friend Google, who knows everything there is to know. First, I searched for



"bottle security tag removal" and ended up with thousands of hits advertising the tags themselves, none of which looked like "mine". There were also the inevitable videos showing how to remove them on YouTube. However, these were mainly posted by idiots describing what they obviously thought were side-splittingly funny removal methods, including the use of shifting spanners, hammers, chainsaws and the like.

There was even one of a guy sitting, straining and appearing to bust a couple of blood vessels while manually working his tag from the neck of the bottle. And it only took half an hour! Unfortunately, all those videos/demonstrations were useless because the tag on my bottle was quite different to theirs. Typical!

I then decided the only way forward was to identify exactly what my tag was and then form a plan of attack to remove it. I could always resort to using tools but as there wasn't much room involved, I thought I'd at least try to be a gentleman about it before resorting to more Neanderthal approaches. As a result, I used a Google image search to try to identify the type of tag involved.

Initially, there were many similar tags but none that were exactly the same, so I kept loading pages until I finally found one that looked similar enough to be useful. Like pretty much all the other search results, it led to either an AliExpress vendor or an AliBaba merchant's page, so if I had wanted to buy 50,000 of them for my supermarket, I'd have found what I'd been looking for.

But that wasn't what I wanted. All I wanted was a means of removing the tag without ruining the contents of the bottle. I was steadily gaining knowledge though; during my search, I discovered that there are two types of tag: RFID and AF. I had no idea what type mine was but, by the looks of it, the removal technique for both types was the same.

After much gnashing of teeth and wringing of hands, I found a merchant's page which stated that this was an EAS security tag and removal was accomplished using any standard detachment tool. As a result, my search now focused on how the tool worked. I assumed that it would somehow involve magnetism, given that I'd seen store workers using either a contoured metal block mounted somewhere on or near the counter or some kind of metal-headed hand-held tool to remove the security tags.

The electronic assembly inside the security tag was nothing more than a simple tuned circuit but releasing the tag wasn't so simple.

Sites focusing on tag removal were few and far between, no doubt to keep information from people with bad intentions. However, by reading between the lines, I eventually figured out that most of these tags were indeed removed using some type of magnetic tool. What's more, the images that I could find of these tools showed what appeared to be a simple block with a permanent magnetic core. This magnetic material "unclipped" something inside the tag to allow removal.

So could I conjure up something similar at home? Some time ago, I purchased a bunch of rare-earth Neodymium magnets for my model aircraft endeavours, so I had plenty of magnets available to experiment with. I gathered together a block of them and they proved to be strong enough to drag a good-sized screwdriver across the bench from 75mm away, so I figured that they should have enough magnetic flux to do the trick.

Next, I placed them in various positions over and around the tag, all the while expecting some sort of audible click or movement to show I'd been clever and hit the right place. Nothing! Nada! Zip! Zilch! As John Cleese once said: "not a @#$% sausage". It was time for a rethink but, in fact, there really was no time to rethink things as zero-hour was fast approaching and to deny one's wife her bubbly is to court familial disaster.

More frantic research on the web implied that magnets placed in two places may be required to unlock it, so I mucked around with that scheme for another five minutes but without success. Obviously, there was more to this removal lark than met the eye.

As I was by now out of time, I grabbed the bottle and headed to my workshop, where I broke out my trusty Dremel rotary tool and its ever-handy mini cutting disk attachment. A couple of messy high-speed slices through either side of the hard-plastic ring, while carefully avoiding the gold foil wrapping around the bottle's neck, soon did the trick. The tag was then prised apart with a screwdriver blade, leaving the clear plastic cup sitting atop the bottle relatively unscathed.

As it came apart, the electronic assembly inside the tag fell out (see photo). It's this that's detected by the large coils on either side of the store exit,

to trigger the alarm.

With the tag removed, I tried to figure out how it worked, in case I faced the same dilemma in the future. By the looks of it, there was some kind of iris-like action that made the ring tighten around the bottle's neck but exactly how this was achieved I had yet to discover. No doubt, many of you are shaking your heads at what a complete philistine I've been but not having seen one of these before, I resorted to cave-man thinking in order to: (1) remove it and (2) learn more about it.

The first thing I did was try to move the now-divided hard-plastic iris ring inside the tag. It seemed very tightly fixed into the tag body but I did manage to manually twist the ring with some needle-nose pliers. It contracted further into the closed position by a few clicks but wouldn't undo back the other way, much like a cable tie worked.

So how did this unlock? The answer lay beneath a plastic block on top of the tag. This was likely the part that fitted into the magnetic detachment tool, so I placed my magnets is various places on, over, beside, near and around the block but there was no satisfying click or movement, so either I was completely off-track or I'd ruined the action when I chopped the tag off.

In the end, there was nothing for it but to use the Dremel's cutting disc again to carefully cut and lift the top of the block away. Inside was a spring-loaded metal ferrule about 6 x 5mm and this was jammed in position, which is why the magnets had no effect on it. Finally the penny dropped; the whole tag needed to be twisted while the magnet pulled the ferrule out of the way in order to remove it. The hard plastic inner ring opened and closed like an iris when the tag was twisted.

As it turned out, I had probably been correct with the magnets and their positioning but too thick to pick up on the fact that I had to turn the tag to remove it while holding the magnets in place. Of course, I've never claimed to be the smartest serviceman on the planet but I did manage to get the tag off without corking or otherwise messing up the bubbly. I just did it in a slightly different way to what the checkout operators would have done!

In the end, the job was done, I learnt a lot and I'll know exactly what to do next time. Like all servicemen at one time or another, I take the good with the bad.

Cat sabotage 1

Following on from my distasteful cat-wee saga in the September 2015 issue, two more similar jobs subsequently turned up at my workshop. The first was a laptop, about eight months old, on which the customer's non-neutered male darling had decided to relieve himself.

Mrs Customer had cleaned the outside of the machine as best she could but whenever she powered the machine up, that all-too familiar smell would build as the machine warmed up until she couldn't bear it any longer. And so it landed in my workshop with a plea to "do something".

These days, I can't afford to be picky and turn down work, so I advised her that I'd pull it apart and clean it as best I could. At the same time, I told her that this substance is acidic and very corrosive and I warned her that if it had reached anything critical inside the laptop, it may not be repairable, even though it was working OK at the moment. She understood the risks and was prepared to at least have it cleaned, if not only to rid the thing of the smell but to at least get some use out of a computer that her insurance company wasn't interested in covering.

Since she'd cleaned the outside quite well, it wasn't too unpleasant to strip it down. Fortunately, the cat had sprayed the screen, so the majority of the liquid had run down the screen and gone between the panel itself and the back of the machine. However, some of the liquid had also crept through the cracks where the battery

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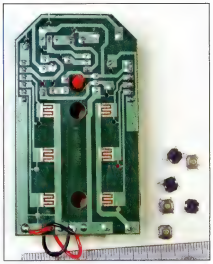
Resurrecting Fan IR Remote Controls

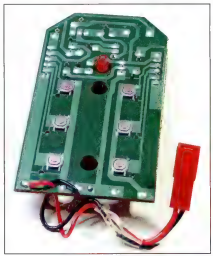
What do you do when the conductive switches in an IR remote control lose their conductivity and the remote stops working? G. C. of Salamander Bay, NSW came up with a simple yet ingenious solution . . .

We have three remote control ceiling fans but after just a few years, two of the remote controls began failing. Eventually, I checked them and tracked the problem down to the conductive rubber switches which had stopped being very conductive.

Over a period of several months, I tried a few fixes, such as conductive paint or aluminium foil glued to the back of the switch, but nothing worked for more than a week. I'd even tried to be bit sneaky and use a learning remote control instead but that didn't work either. The fan remote controls used non-standard encoding and the learning remote failed to respond.

As a result, for the past two years or so, I've been putting up with three fully working fans but only one working remote control. And that's resulted in a lot of running around looking for this remote when a particular fan needed to be controlled.





The photo at top right shows the unmodified remote PCB, while below it is the modified PCB with the switches soldered in position.

And then, as I awoke one morning, I had an epiphany, a real Eureka moment if you like – why not totally bypass the conductive rubber and use a tiny "real" switch instead? In fact, I already had some of these minuscule switches which measure just 4 x 4 x 1.5mm and are used in many car remotes. They are easily found on eBay (search for "SMD Tactile Push Button Switch") and 50 of them cost less than $US5.00.

I pulled a non-working remote control apart (again), looked at the switch tracks on the PCB and looked at the switches. I found that they were actually going to fit so I reached for my soldering iron and 30 minutes later, had installed the switches in both non-working remotes.

For the first time in years, both remotes are now working perfectly. All I needed were six switches, a magnifying glass and a steady hand.

was mounted and had entered the laptop that way.

Once open, I could see that most of what had come inside had ended up pooled underneath the top-left corner, right where the CPU's heatsink and fan assembly sat – hence the stink when it was fired up. Some had also hit the main board but in an area where there were no electronic parts at all. This was indeed lucky, considering the damage that could have resulted if the liquid had hit any areas populated with components.

After removing the motherboard, I could see where the pool of wee had semi-dried into a gel-like substance which stunk to high heaven. I removed all the satellite boards and speakers and took the now-empty bottom half of the chassis and flushed it with lots of warm, soapy water. I then thoroughly dried it before spraying it with a product especially designed to counteract the specific odour of cat spray.

It was interesting to note that the cat's wee had even corroded the paint used to colour the laptop. There is always some over-spray inside the chassis and it stands out against the coppery-coloured plastic base.

After I reassembled the laptop, it smelled a bit like a public toilet due to the citrus-based fragrance I used. However, this will fade over time and will be easier on the nose. What's more, it's a whole lot better than the alternative!

Cat sabotage 2

My second job courtesy of an errant cat involved a keyboard player's stage amplifier. It had come in for servicing due to "crackly" controls and a buzzing reverb channel.

This beast is a large cabinet amplifier with inbuilt 15-inch speaker and as soon as the customer rolled it in, I could smell the all-too-familiar scent of feline waterworks. I immediately mentioned it to him but he hadn't even noticed, so I'm not sure what his van smelled like. However, once I had made him aware of it, he agreed that the amplifier was a bit "whiffy".

It seems that the neighbour's cat had come into his garage, where the amplifier is normally stored, and relieved itself all over the front of the cabinet, soaking the grille cloth and staining the vinyl/leatherette covering. It was just what I needed – another clean-up job before I could even get down to the problems it had been brought in for. Unfortunately, I won't be able to just throw the speaker or the cabinet into a tub and jet-wash it but the thought has crossed my mind, to be honest.

The outside won't be too bad to clean; any good cleaner and a splash of polish will restore the sheen to the covering. However, I will have to remove the speaker to clean the cone and to rinse out the grille cloth.

When I looked inside the cabinet, I found that the liquid had also pooled into the bottom where the cleats join the front baffles. I'll just have to scrub it out as best I can when the time comes.

The amplifier chassis itself lives at the very top of the metre-high cabinet, so it escaped the worst of the cat spray. However, it looks like it has been on the road for many years and, as a result, it has the usual build-up of nicotine, beer, wine and sweat that all hardware seems to accumulate after years of work in the rock-and-roll world.

It doesn't take much effort to use a wet-wipe to clean the dashboard of an amplifier but nobody seems to place much store in carrying out even simple maintenance like this. I guess it's just not "rock and roll" as far as the roadies or players are concerned.

Hopefully this will be the last time anyone brings in cat-stained hardware for repair – at least for the time being.

Dishwasher repair

K. S. of Dunedin, NZ drew on his past experience in the service business to fix his dishwasher. Despite that, things didn't exactly go to plan . . .

Many moons ago, I used to run a retail shop and an electrical service centre which employed a full-time serviceman. We fixed anything that could be plugged into the 240VAC mains and then some. Radios, toasters, TVs, electric fence units, intercoms . . . you name it and we fixed it.

Because I was in charge, I also had to be familiar with all of the intricacies of the service and repair side of the business. This was essential as Brian (not his real name) was prone to overindulge on the liquid stuff of hangover fame and would quite often not come in on Mondays.

In those days, people actually kept things and had them repaired. They also expected their appliances to be ready when promised. Brian's bench and the surrounding shelves and floor were always full; he was not a tidy person but he could do something that I could never achieve. His always cluttered bench was fed by at least 10 dual 240VAC outlets on the wall immediately above and from these hung various extension cords, these being the old rubberised type with large moulded composition outlets.

Brian advised me that the workshop was his domain and that I would tidy it at my peril. He went further and suggested that he could pick up any cord and tell whether it was live just by holding the cord in his hand, irrespective as to whether or not it actually had current running through it.

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

Thinking that I'd get one back on him for all the repairs that I'd had to undertake in his rat's nest, I challenged him to come in the next morning and, with his back to the mains outlets, correctly nominate which of about 12 extensions were actually live at the wall switch. To my amazement he got every one correct even though I'd switched the extensions randomly and had also tangled them on the bench (they were all black rubber).

Later that day, a customer brought a vintage car in to have a radio fitted out of sight under the timber dash. The motor had a vertical stand-alone magneto with four large multi-part spark plugs. To press home his advantage, Brian advised me, in front of the customer, that he could place the fingers of each hand between the tips of the energised spark plugs and the cylinder head and stop the engine without flinching.

And that's exactly what he did. Whether the excess alcohol in his system desensitised his hands and dulled his brain so that the magneto had no apparent effect on him or whether he just toughed it out I will never know.

I haven't done much servicing since those days but recently our Whirlpool dishwasher decided to stop dead. I dragged out my trusty VTVM and then proceeded to turn the water off. I then unplugged the machine from the mains and tipped it over on its side in order to reach the innards under the lower panel. What a disaster! The pump, sump and hoses were full of water and it all came pouring out onto our newly-lacquered floor.

I righted the machine, fetched a trolley from the basement and proceeded to wheel the machine outside. That was my second mistake – the step has an internal raised portion and this, at the velocity that I was attempting to propel the aforesaid Whirlpool over it, jammed the rubber tyres onto the side of the unit and propelled yet another burst of water on to the floor.

In frustration, I pushed the dishwasher trolley hard over the door sill in one fluid movement. However, in the process, the water on the floor impeded my own progress and I slipped, landing flat on my back in the middle of the aforesaid water.

The machine then sat outside unattended for a few days while I recovered. Finally, on a fine afternoon, I plugged it in via an isolation transformer and it gave an "F1" fault code with matching beeps. I gave it a thorough visual inspection, replaced all the hose clamps, checked the float switch, removed the NTC thermistor and ran it under a hot tap before checking its resistance and, finally, checked the heater-element resistance. All were OK.

I then proceeded to hook up an outside garden hose and pushed the run button. Nothing happened. I then discovered that the inlet solenoid, which I had already checked for continuity, had an intermittent open circuit and so it was replaced. I then powered it up again and it ran through all six cycles perfectly.

Feeling rather pleased with myself, I reinstalled it under the kitchen bench and pushed the run button again – F1, beep beep beep! Just what I needed.

I took it back outside, checked it over again with my trusty meter and ran it again. It ran perfectly, so I repeated the installation in the kitchen and got F1, beep, beep, beep yet again.

Logic now told me that the only differences between the outside and inside installations were the inlet hose and the water supply itself. I went down to basement and removed the hose from the supply tap, which is in the wall cavity. I then reached in and turned the tap on, only to have high-pressure water bounce off the wall and saturate me. Unprintable words followed! I then reconnected the hose and repeated the start-up procedure in the kitchen – gurgle, gurgle, gurgle, wait F1, beep, beep, beep. Aaagghh!!

The problem? The spring-loaded O-ringed pressure regulator mounted inside the inlet hose adjacent to the supply tap was faulty. SC

By JOHN CLARKE

Check your turntable's speed with this white LED strobe

So you have dragged out the old turntable and are playing vinyl records again. Good. But how do you know that the turntable speed is correct? The old way to do it was to use a circular disc with strobe markings but that does not necessarily work these days. Why not? Read on.

PLAYING VINYL records has made a big comeback in recent years and many people are resurrecting their old turntables or buying new ones. But there are a few hurdles before you get the optimum result, such as making sure the cartridge stylus is not worn out and that your preamplifier provides the correct equalisation.

On a more prosaic note, many turntables which have been out of action for decades may not necessarily operate at the correct speeds of 33.3, 45 and 78 RPM. So you need to check that aspect. How do you do that?

The old tried and true method was to use a circular card which had stroboscopic markings on it and run the turntable under mains voltage lighting; 230VAC 50Hz in the case of Australia, New Zealand and most of Europe or 120VAC 60Hz in the case of the Americas, parts of Japan, Asia etc.

These stroboscopic cards have four or six bands of markings and depending on the speed selection, one of those bands would appear to be stationary. The reason for this was that incandescent or fluorescent lighting had a strong 100Hz or 120Hz component and this would act to make the relevant strobe band on the circular card appear to stop moving.

The same method applies to those turntables that have strobe markings on the rim of the platter. But while the principle is still correct, it does not work very well in most homes these days. Why not? Because our political

masters have deemed that old-fashioned incandescent lights are "wasteful" and "bad for the environment". At the same time, fluorescent lighting in most homes is now out of fashion, unless it is using those ugly compact fluorescent lamps (CFLs) with their unnatural hues and copious electromagnetic interference.

So why can't these modern lamps provide the same stroboscopic effect? The reason is that they run at much higher frequencies so that any residual AC component in the light output is very small. This applies to any lighting which uses electronic ballasts.

Mind you, even when you are using incandescent or fluorescent lighting powered by 50Hz or 60Hz mains, the strobing effect is not particularly strong and it is even weaker with halogen lamps with their much hotter filaments. We will explain why later in this article.

Turntable types

Most good turntables are either belt-driven or direct drive. Cheaper turntables were driven from an idler wheel inside the rim of the platter. The belt-driven types usually have a small synchronous motor which can be assumed to be locked to the mains frequency, provided the belt is not slipping on the motor shaft. This could happen if the belt is perished, kinked or hardened. Idler-driven turntables typically have a shaded pole motor and they are not so tightly locked to the mains frequency (and because of the idler-drive, they are more likely to produce rumble).

Direct drive turntables should run at the correct speed but again, that cannot be taken for granted. Also some direct drive turntables had or have a variable speed feature which allows the music pitch to be shifted over a a range of about a semitone. Again, how do you know what is the correct speed setting (unless you have absolute pitch)?

Any substantial speed variation is liable to cause any music to sound off-pitch. And if you want to dance to records and the number of beats per minute is important, then again, the turntable speed should be correct.

Our solution has been to design a white LED stroboscope which produces one millisecond pulses of light at a very precise 100Hz or 120Hz (ie, twice the mains frequency). But our recommendation is to use it at 120Hz to give the most accurate speed indication with a strobe card.

So why is that? Funnily enough, a lot of strobe cards are not necessarily accurate and if you want the most accurate speed indications at 33.33 and 45 RPM, you should use a strobe pattern designed for 60Hz operation. Interestingly, as far as 78RPM records are concerned, it is not possible to get an absolutely accurate speed indication at 100Hz or 120Hz but 100Hz is the more accurate, with a speed error of 0.1%.

Because of these issues, we have also designed a PCB strobe disc that you can place on your turntable to check its speed. It is just the right size to fit on the record label and will not cover the playing area. Since it is precisely etched and machined, it will not have the common fault of some printed strobe discs which can be slightly off-centre or the centre hole is a little over-size.

A turntable rotating at the correct speed will have one band of the strobe disc markers remaining stationary. If the markers drift clockwise, then the turntable speed is fast and if the markers drift anticlockwise, the turntable speed is too slow. Any slight wavering forwards or backwards of the markers will be due to irregular speed variations and significant variations of this nature and may be audible as "wow and flutter".

What can be done about a turntable that doesn't run true to speed? More information on this is detailed in the above panel.

Our LED Turntable Strobe is built on a small PCB that fits into a small plastic utility box. Alternatively, the PCB can be installed inside the turntable cabinet and the strobe LED can be mounted to illuminate strobe markings on the platter's rim. It can be powered with a 9V battery, an external DC supply or a 5V supply via a USB connector.

Circuit description

Fig.1 shows the circuit and it is based on a PIC12F675 microcontroller (IC1). The microcontroller vastly sim-

Turntable Speed Variations

Turntables that rely on a 50Hz or 60Hz mains supply to drive a synchronous or shielded pole motor may not necessarily run at the correct speed. Typically, the 50Hz mains frequency can vary between 49.85Hz and 50.15Hz (ie, ±0.15Hz) over the course of a day. Typically, the mains frequency will be slightly low during periods of peak power demand and a little high at other times.

That variation would mean that middle C could be as low as 260.841Hz and as high as 262.411Hz. Whether this is noticeable or not depends on how well you discern pitch.

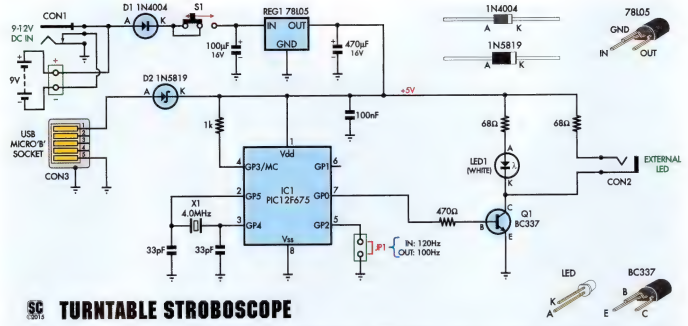
Further turntable speed problems can be present if an incorrect-sized pulley on the motor spindle is used to drive the belt. This could be because you have an imported turntable that's been designed to operate from 60Hz instead of 50Hz (or instead designed to run with 50Hz instead of 60Hz). You may be able to supply the correct voltage for the motor using a transformer but the frequency will not be correct.

For precision speed from a synchronous motor drive, an electronic driver circuit could be used to produce a suitable sinewave source for the motor. This could be a low-powered crystal locked sinewave inverter such as for an uninterruptible computer supply. Modified sinewave inverters may not be suitable since the square wave supply may introduce noise into the motor and cartridge pick-up leads.

Why Is This White LED Strobe Necessary?

In the "olden days" the usual method of providing a strobe light source involved using an in-built Neon discharge lamp powered from the 240VAC 50Hz or 120VAC 60Hz mains supply. The neon would produce light pulses at 100Hz or 120Hz and this would give a stationary pattern for the set speed.

However, using the mains supply is most unlikely to give a completely steady strobe pattern when you are using a crystal-controlled direct-drive turntable unless the mains frequency is precisely 50.000Hz or 60.000Hz. Even a slight error will cause the strobe pattern to rotate slightly. Of course, with a belt-driven synchronous motor turntable, you would never be aware of these speed errors (unless you build our Turntable Strobe).



TURNTABLE STROBOSCOPE

Fig.1: the circuit is based on a PIC12F675 microcontroller (IC1), with 4MHz crystal X1 used as the reference clock. Pin 7 of IC1 drives transistor Q1 to flash white LED1 while jumper JP1 sets the strobe frequency to 120Hz or 100Hz.

plifies the circuit, compared to using a separate crystal oscillator and dividers. In addition, the microcontroller makes it easy to incorporate 100Hz and 120Hz operation.

IC1 uses a 4MHz crystal as the reference clock for its program to run the strobe. The un-calibrated accuracy of the crystal (typically 50ppm) is sufficiently accurate for the strobe. IC1 internally divides the 4MHz frequency by four, so that the program runs at 1MHz. Single clock instructions of the program are therefore 1µs in duration.

As already noted, the strobe LED is driven with 1ms pulses and this gives a duty cycle of 10% at 100Hz or 12% at 120Hz. This will ensure that the strobe disc markings appear quite sharp. Longer pulse durations will cause noticeable blurring of the strobe pattern as the markings move further during the on-period. This is a distinct advantage of our LED strobe compared to the light from an incandescent lamp powered from a 50Hz or 60Hz mains supply, with the resultant display being quite indistinct by comparison.

Designing The Strobe Disc

We have designed our strobe disc to suit 120Hz operation for 33.33 RPM and 45 RPM. We have also provided a strobe band for 78 RPM at 120Hz but it will produce a speed error of -0.325%. To counter that, we have also provided a 78 RPM strobe band for 100Hz operation and this will have a speed error of -0.1% (close but no cigar). Mind you, precision speed setting at 78 RPM is not so important because most records from that era were not cut at a precise 78 RPM.

Note that there are lots of strobe disc patterns that can be down-loaded from the internet but most are incorrect. They may be correct at one speed, say 45 RPM, but incorrect at 33.3 RPM or 78 RPM. As an example, some patterns are designed for 33 RPM, not the correct value of 33.33 RPM.

If you already have a strobe disc, how do you check that the pattern is correct? It's a simple calculation. Just multiply the strobe frequency (100Hz or 120Hz) by 60 to convert to pulses per minute. Then divide the turntable speed in RPM into this number. So 33.33 RPM requires 100 x 60 ÷ 33.33333 or 180 bars for a 100Hz strobe or 216 bars for 120Hz. It's not possible to obtain a correct pattern for 45 RPM at 50Hz, since the number of bars is not an integral number; it is 133.333. So any card with 133 bars is doomed to error.

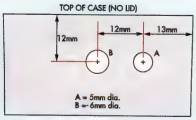
If you want to be sure of the result, use our strobe disc.

The white LED (LED1) is driven via transistor Q1 and a 68Ω resistor connected to the +5V supply rail. Q1 is switched on and off by the GP0 output of IC1, using a 470Ω base resistor. The LED is driven at a nominal current of 29mA, assuming a 3V drop across the LED.

Connector CON2, a 3.5mm jack socket, is provided so that an external LED can be connected.

We have provided several options for the power supply: a 9V battery, a 9-12V DC plugpack via CON1 or 5V via a micro-USB "B" socket. If using a 9V battery or a DC supply via CON1, the 78L05 3-terminal regulator (REG1) provides 5V to the micro. Alternatively, if you are using a 5V USB supply, this is fed to the micro via Schottky diode D2. **If you intend using a USB power source exclusively, you can omit the other supply components such as CON1, D1, switch S1, REG1 and the 100µF capacitor.**

For those interested in the effects of the strobe flash length, you can select a 2ms flash duration by tying pin 6 of IC1 to pin 8 using a short piece of wire under the PCB. This will set the strobe to flash for 2ms but it will still run at 100Hz or 120Hz, as selected with JP1. This change needs to be done while power is off. A return to a 1ms flash duration will only occur when pin 6 is disconnected from pin 8 with power switched off and on again.



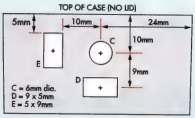


Fig.2: the two end-panel drilling templates. They can either be copied or downloaded as PDF files from the SILICON CHIP website.

The program checks the GP2 input level and produces the 100Hz strobe signal when this input is high at 5V. It produces a 120Hz signal when the input is low. The GP2 input is pulled high via an internal pull-up resistor in IC1 when JP1 is out and is pulled low when jumper shunt JP1 is inserted. The jumper setting can be altered while the strobe is operating and the strobe frequency will change immediately.

Drilling the case

The Turntsable Strobe is housed in a UB5 plastic utility box (83 x 54 x 31mm) with holes cut in one end for the LED and the external LED socket (if fitted) and in the other end for the on/off switch, the DC socket and micro-USB socket.

It's necessary to drill and cut the case before installing any parts on the PCB. There are a few options here, though. First, if you will be running the unit from battery power only, then there's no need to cut holes in the case for the DC socket and the micro-USB socket and these two parts can be left off the PCB. Alternatively, if you will be supplying power via the DC socket or micro-USB socket only, then the battery and on/off switch can be left out and there's no need to cut a hole for the switch.

You could also leave out either the DC socket or the micro-USB socket, depending on the external supply.

At the other end of the case, you can leave out the 3.5mm jack socket if you don't intend using an external LED.

By the way, the micro-USB input does not have to connect to the USB port on a computer. Any USB output from a 5V plugpack or power board can be used to supply power. Some modern turntables even include a USB port on the turntable plinth.

The first job with the case is to remove the internal ribs on each side and this can be done using a small pair of sidecutters. You can then finish off by using a sharp chisel to remove any remaining rib material.

The next step is to use the PCB as a template to mark out its three mounting holes in the case. That's done with the PCB sitting inside the case and pushed hard against two of the side pillars (see photo). The PCB is then removed and the mounting holes drilled to 3mm. Countersink these holes on the outside of the case using an oversize drill.

You now have to cut and drill the holes in the end panel and that's done using the templates shown in Fig.2. These templates can either be copied from the magazine or downloaded in PDF format from the SILICON CHIP website and printed out.

Once you have the templates, cut them to size and attach them to the end panels using adhesive tape. Be sure to attach the correct template to its panel – the template with the two circular holes must go on the end that matches the LED end of the PCB.

It's now just a matter of drilling and cutting the holes in the panels as required. The square cut-outs for the micro-USB socket and switch S1 can be made by drilling a series of small holes in a row, then joining them and filing to the required shape.

Note that it's a good idea to always use a 1mm pilot drill to start the holes (to ensure precise location) and then enlarge them to the required size using successively larger drills.

PCB assembly

All parts (except the battery) are mounted on a PCB coded 04101161 and measuring 79 x 31mm. Fig.3 shows the parts layout. Begin by soldering the surface mount micro-USB socket (if used) to the underside of the PCB, then flip the board over and install the resistors on the top side. Table 1 shows the resistor colour codes but it's also a good idea to check each one using a digital multimeter before soldering it into place.

Follow with diodes D1 & D2, making sure that the 1N5819 is used for

Parts List

1 PCB, code 04101161, 79 x 31mm
1 set of turntable templates (see text)
1 UB5 case, 83 x 54 x 31mm
1 4MHz crystal (X1)
1 DIL8 IC socket
1 SPDT vertical slider switch (Altronics S 2071) (S1)
1 2-way header (2.5mm pin spacing) (JP1)
1 pin header shunt
3 6.3mm tapped Nylon stand-offs
3 M3 x 5mm countersink head screws
3 M3 x 5mm machine screws
1 Micro-USB type B socket (CON3) (FCI 10103594-0001LF) (**au.element14.com** – Part No. 2293752)
1 PCB-mount DC socket (CON1)*
1 9V battery*
1 9V battery snap connector*

Semiconductors

1 PIC12F675-I/P microcontroller programmed with 0410116A.hex (IC1)
1 78L05 regulator (REG1)*
1 5mm white LED (LED1)
1 BC337 NPN transistor (Q1)
1 1N4004 diode (D1)*
1 IN5819 Schottky diode (D2)

Optional external LED parts

1 5mm white LED
1 switched stereo 3.5mm PCB-mount jack socket (CON2)
1 mono 3.5mm jack plug
1 length of single cored shielded cable
1 100mm length of heatshrink tubing (1mm and 5mm)

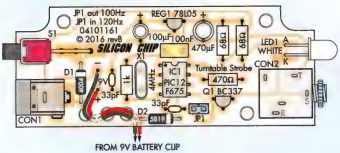
Capacitors

1 470µF 16V PC electrolytic
1 100µF 16V PC electrolytic*
1 100nF MKT polyester
2 33pF ceramic

Resistors (0.25W, 1%)

1 1kΩ
1 470Ω
2 68Ω

***Note:** omit DC socket CON1, diode D1, switch S1, the 100µF capacitor, regulator REG1, the 9V battery and the battery snap connector if the unit is to be exclusively powered via the micro USB socket.



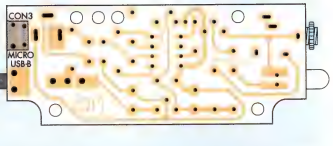
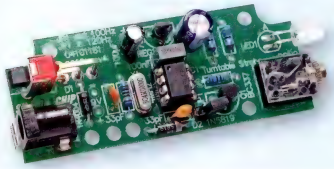
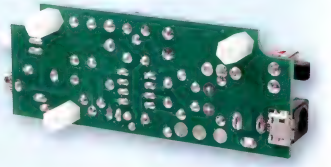


Fig.3: follow these two parts layout diagrams and the photos below to assemble the PCB. The micro-USB socket (CON3) should be soldered to the underside of the PCB first, after which the remaing parts are installed on the top side.





Left: inside the completed unit. The battery and switch S1 can be omitted if the unit is to be powered only via the DC socket or micro-USB connector. Similarly, CON2 can be left out if you won't be using an external LED.

D2. Make sure also that D1 & D2 are correctly orientated. The DIL8 socket can be then installed, followed by the 100nF capacitor and the two 33pF ceramic types.

Crystal X1, transistor Q1 and REG1 are next on the list but don't get Q1 & REG1 mixed up. The two electrolytic capacitors can then go in, along with the 2-way pin header (the header's shorter pins go into the PCB). Once the header is in place, install the jumper shunt (ie, to short the pins) so that the unit will operate at 120Hz.

As explained earlier, DC socket CON1, jack socket CON2 and switch S1 are optional. CON1 is required if you are using a 9-12V DC plugpack (ie, one with no USB output) to power the unit, CON2 if you are using an external LED and S1 if you are using battery power. If you are using a DC plugpack to power the unit (via CON1) but will not be fitting a battery, switch S1 can be replaced by a wire link.

LED1 is installed by first bending its leads down by 90° exactly 10mm from its plastic body. Make sure that it is correctly orientated before doing this though (the anode lead is the longer of the two). The LED is them mounted with its leads 4mm above the PCB (use a 4mm thick spacer to set this height), so that the centre of its lens lines up with the adjacent jack socket.

The last part to connect is the battery snap. Feed its leads through the stress relief holes as shown in Fig.3 before soldering them to the PCB.

If you intend using an externally connected LED, this can be now wired to a length of single-core shielded cable. Connect the centre lead to the LED's anode and the shield wire to

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
100nF	0.1µF	100n	104
33pF	NA	33p	33

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	1	470Ω	yellow violet brown brown	yellow violet black black brown
❑	2	68Ω	blue grey black brown	blue grey black gold brown

These two views show the completed unit. Note that some of the holes in the end panels can be omitted, depending on the options chosen when you build the unit (see text).

the cathode. The other end of the cable is then terminated in a 3.5mm jack plug, with the centre lead going to the tip contact and the shield to the outer sleeve contact.

Final assembly

Now for the final assembly. First, attach three M3 x 6.3mm tapped Nylon stand-offs to the PCB mounting holes and secure them using M3 x 5mm machine screws. The PCB assembly is then installed by angling it down into the case so that LED1 and CON2 pass through their respective holes, then squeezing the sides of the case together and pushing the other end of the PCB down until the switch and micro-USB socket go into their panel cut-outs.

The PCB is then secured in position using three M3 x 5mm countersink-head screws which go through the base and into the stand-offs. Once it's in place, fit the battery snap to the battery and slide the battery into the case as shown in the photo.

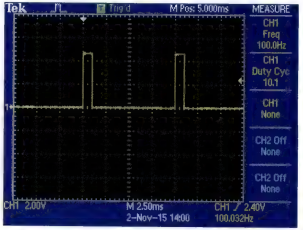
Testing

Now for the smoke test. Apply power and check that there is 5V (4.85-5.15V) between pins 1 and 8 of IC's socket (or 4.5-5.2V if using USB power). If this is correct, switch off and install IC1 (watch its orientation), then reapply power and check that the LED lights.

If it does, then your Turntable Strobe is working and you can attach the lid which now becomes the base of the unit. If you now move the unit rapidly from side-to-side with the LED viewed side-on (ie, not looking directly into the lens), it should be seen to light in several different positions. That indicates that the LED is being flashed on and off. By contrast, if you look directly at the LED when it is stationary, it will appear to be continuously lit due to its 120Hz flash rate.

Finally, if you have made up an external LED cable, plug it in and check that its LED also operates.

Fig.4: this screen grab shows the waveform at the GP0 output, pin 1, of IC1. In this case, the circuit is set for 100Hz operation (JP1 out). The LED is lit for 1ms at a 10% duty cycle. Ignore the error of the displayed 100.032Hz which is because the oscilloscope frequency calibration is not particularly precise.



Dataflex/Datapol Labels

(1) For Dataflex labels, go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_60&products_id=335
(2) For Datapol labels go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_55&products_id=326

Front panel label

The front-panel label is available in PDF format on the SILICON CHIP website. It's just a matter of downloading it and printing it out onto an A4 sized synthetic Dataflex or Dataplex sticky label (see panel). This label is then attached to the top of case (ie, not the lid), as shown in the photos.

Fig.4: the front panel label can be downloaded as a PDF file from the SILICON CHIP website.

Alternatively, you can print out a paper label and attach this using double-sided tape. That's it – your Turntable Strobe is ready for use. SC

Design by JOHN CLARKE

Speech Timer For Contests & Debates

If you are involved in school or university debating contests or in Toastmasters International, you will be aware of the importance of a speech timer. It keeps meetings and events on time and also prevents individual speakers from droning on past their allotted time. The timer presented here has a large 3-digit display plus three large LEDs and a buzzer. Plus, it has a tiny infrared remote control.

THE INITIAL impetus for this Speech Timer project came from a member of Toastmasters International who was concerned at the primitive timer employed at his club. Could we design a timer which met Toastmasters International rules but did not involve an olde-worlde mechanical timer and three crudely switched coloured lights?

Well, of course we could! Mind you, Toastmasters rules do not make any mention of 3-digit LED 7-segment displays – those rules were drawn up over 80 years ago when carbon-zinc batteries and incandescent lamps were state-of-the-art technology! Microcontrollers, light emitting diodes and infrared remote controls would have been unimaginable!

So our Speech Timer provides the basic green, amber and red warning lights plus a manually-operated final alarm, as required for speeches defined by Toastmasters' rules. It also provides a 3-digit up/down timer, all controlled by a cheap microcontroller.

Specifically, we have incorporated preset time periods that match Toastmasters International rules for various speech lengths. Table 1 shows the details.

These time periods are based on the

Features & Specifications

Features

- Battery and/or DC plugpack operation
- Readout on large 7-segment displays
- Visual warnings via green, amber and red indicator lights
- Audible warning buzzer (manually-operated)
- Optional automatic visual warning operation
- Manual visual and buzzer warning control
- Separate duplicated warning lights for timekeeper and speaker
- Dimming of main display and warning lights
- Volume adjustment for audible warning signal
- 99-minute maximum time period
- Preset Toastmasters' contests and other presets included
- Minutes and tens-of-seconds display (seconds display accessible)
- Infrared remote control operation
- Reset, pause and start timer controls
- Blue acknowledge LED for IR signalling
- Low battery indicator

Specifications

- Power: 12V DC @ 100mA
- Current drain: 76mA typical at full brightness; up to 100mA with warning LED and Alarm on
- Audible alarm: 1.22kHz tone modulated at 200Hz
- Display multiplexing: 100Hz
- Low battery indication: warning turns on below 8.8V and off above 8.92V (voltage sampled at 3.3-second intervals)
- Latency: ~18ms from press of IR remote button to timer response

Fig.1: this artwork is attached to the top of the case and shows the button assignments on the remote control.

July 2015 to June 2016 Speech Contest Rule Book. By the way, there are apps and software to time speeches at Toastmasters' meetings but these are not really useful when they must be seen by a room (or even a hall) full of people.

Naturally, the Speech Timer can also be used to time speakers in debating contests and meetings. In fact, it can be used anywhere a highly-visible digital timer is required. By default, it counts up but it can also be made to count down (see panel later in the article).

Presentation

The Silicon Chip Speech Timer is housed in plastic case with the 3-digit 7-segment LED display on the front. Down the righthand side are the three large LEDs, arranged like traffic lights with red at the top, amber in the middle and green at the bottom of the stack. These are duplicated on the rear of the case, together with the small loudspeaker which provides the ending buzzer.

The Speech Timer can be placed in the room so that the audience and the speech timer can see the 3-digit display, while the speaker can only see the green/amber/red LEDs when they are lit.

The Speech Timer can be run from an internal battery (eight AA alkaline cells) or from a 12V DC plugpack. You can also use NiMH or Nicad cells instead of alkalines and these can be trickle charged via the 12V plugpack.

Remote control

Apart from an on/off switch mounted near the socket for the DC plugpack, there are no controls on the unit. Instead, all functions are set by a tiny remote control, made by SparkFun – the same unit as used in our 9-Channel Remote Control in the September 2015 issue.

This remote measures just 80 x 40 x 7mm and is powered by a CR2025 3V cell. It has nine pushbuttons or more correctly, small snap-action domes. The buttons are Power (shown as a circle logo with a stroke through the top), A, B and C and a 5-button array.

We have assigned the buttons as shown in Fig.1. The power button is used for controlling the display brightness while buttons A, B and C are the warning indication controls: A for manually sound the **A**larm, B for the warning LED **B**rightness and C for manually **C**ycling through the warning LEDs. The functions of the 5-button array are described later in this article.

A tiny blue LED on the Speech Timer's front panel flashes to acknowledge signals from the infrared remote control and it doubles as a low-battery indicator, staying lit when the battery voltage is low.

Circuit description

Fig.2 shows the complete circuit of the Speech Timer. It's based on a PIC16F88 microcontroller (IC1) and this drives the 3-digit 7-segment LED display and warning LEDs (via transistors Q1-Q8 and IC2 & IC3). IC1 also monitors the output from the infrared receiver (IRD1) and the supply voltage.

Each of the LED display segments comprises four series-connected LEDs evenly spaced apart and there are two series-connected LEDs for the decimal point. When a segment is lit, it will typically have 7-8V across the four series-connected LEDs.

That presents a design problem since IC1 requires a 5V supply while the displays need to be driven from a supply voltage of 12V. We solved that conundrum by tying IC1's positive (Vdd) supply rail to the +12V supply rail, while its negative rail is supplied from a 7905 3-terminal regulator.

The segment anode lines of the 3-digit display are driven by PNP transistors Q1-Q8 (for the seven segments plus the decimal points). The emitter of each transistor is connected to the

Table 1: Preset & Manual Time Periods (Counting Up)

Type	Length (minutes) (Display when unit reset)	Green Warning (elapsed minutes)	Amber Warning (minutes or minutes:seconds)	Red warning (elapsed minutes)	Disqualification Minimum Period (minutes:seconds)	Disqualification Maximum Period (minutes:seconds)
Any (manually operated)	0:0	when selected	when selected	when selected		
Table Topics*	1-2	1	1:30	2	1:00	2:30
Evaluation*	2-3	2	2:30	3	1:30	3:30
Tall Tales*	3-5	3	4	5	2:30	5:30
International & Humorous*	5-7	5	6	7	4:30	7:30
Speech1	10'	7	9	10		
Speech2	15'	10	13	15		
Speech3	20'	15	18	20		
Speech4	30'	20	25	30	* Denotes Toastmasters contests.	
Speech5	40'	30	35	40	' is the symbol for minutes	
Speech6	50'	40	45	50		
Speech7	60'	50	55	60		
Speech8	70'	60	65	70		
Speech9	80'	70	75	80		
Speech10	90'	80	85	90		

+12V supply and the collector connected to the segment anode via an 82Ω current-limiting resistor or via a 180Ω resistor for the DP (decimal point). Each segment line is driven when the base of its transistor is pulled low by the respective output of IC1. When the base is taken high (ie, +12V), the transistor is switched off and the segments are off.

As shown on the circuit, outputs RA3, RA4, RB1, RB2, RB4, RA0, RB7 & RA2 of IC1 connect to the bases of transistors Q1-Q8 via 470Ω resistors.

The three common cathode 7-segment displays are multiplexed. This means that the seven anode segments and the decimal points of the digits are driven by the eight transistors and then each digit is turned on for about one-third of the time by pulling its common cathode low.

For a digit to light, its common cathode needs to be connected to the 0V line of the 12V supply. But we can't directly do this via any of IC1's outputs since IC1's negative rail (GND) is only 5V below the +12V supply rail. So the circuit needs level shifting from the negative rail of IC1 to 0V.

IC2 & IC3 take care of this level shifting requirement and drive the common-cathode connections at the same time. IC2 is a 4051 analog single-pole 8-way switch that's used as a single pole 4-way switch. IC2 can connect its common pole contact "Z" at pin 3 to one of the Y0, Y1, Y2 & Y3 terminals. Which connection is made depends on the logic level at the A0 and A1 inputs and that is under the control of IC1.

IC2 has separate supply rails for the control inputs (Vss) and for its output switching (Vee). Vss, pin 8, is connected to ground, the negative supply line for IC1, while Vee is tied to the 0V rail. So IC2 does the signal level shifting.

The A0 and A1 inputs of IC2 are driven from the RB6 and RB5 outputs of IC1 respectively. When both inputs are low, the Y0 output of IC2 connects to the Z pole contact of IC2 and is pulled high via a 4.7kΩ resistor. This output then drives the 4B input of IC3.

IC3 is a ULN2003 7-Darlington transistor open-collector driver. We use four of these Darlingtons to separately drive the common cathodes of the 7-segment displays and the common cathodes of "traffic light" LEDs 1-6 and the acknowledge/low battery indicator LED (LED7). When 4B is driven, the 4C collector (pin 13) connects the common of display DISP1 to 0V, so that digit lights up.

Other combinations of the A1 and A2 inputs select the Darlington transistors at IN5, IN2 and IN3. For example, when A1 and A2 are both high, IC2's Y3 output drives 5B of IC3. IC3's 5C collector then connects the common of DISP2 to 0V and the second digit lights up, and so on.

We drive DISP1 for 2.5ms, then DISP2, DISP3 and then the LEDs, all for the same 2.5ms period.

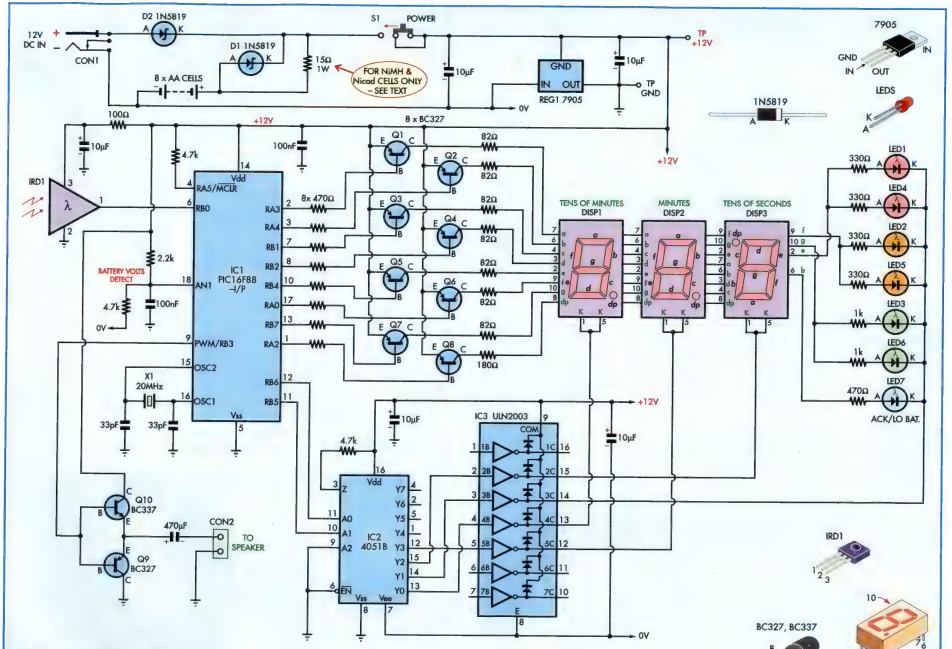
Flashing colon display

Note that the connections to DISP3 are mixed up compared to the connections to DISP1 & DISP2. For example, the "A" segment for DISP1 is connected to the "A" segment of DISP2, but this connects to the "F" segment of DISP3. The reason for that is partly due to the fact that DISP3 is actually mounted upside down compared to the others, so that we can have a flashing colon between DISP2 & DISP3.

Also, the connections to DISP3 have been done in this way to make the PCB pattern practical. Which segments are driven for each display is sorted out in the software for IC1, so the different connections for DISP3 do not matter.

Several different resistor values are used for driving the displays and LEDs. We use 82Ω for the segments but the decimal points for DISP1-DISP3 use a 180Ω resistor. This is because the decimal points have only two LEDs, compared to four in the segments.

A similar comment applies to the indicator LEDs, where the resistor values are selected to produce a similar brightness to the 7-segment displays. For the red and amber LEDs, 330Ω re-



SPEECH TIMER

Fig.2: the Speech Timer circuit is based on a PIC16F88 microcontroller (IC1). This drives a 3-digit 7-segment LED display, six warning LEDs (LEDs1-6) and a blue acknowledge LED (LED7) via transistors Q1-Q8 and IC2 & IC3. IC1 also monitors the output from the infrared receiver (IRD1) and the supply voltage.

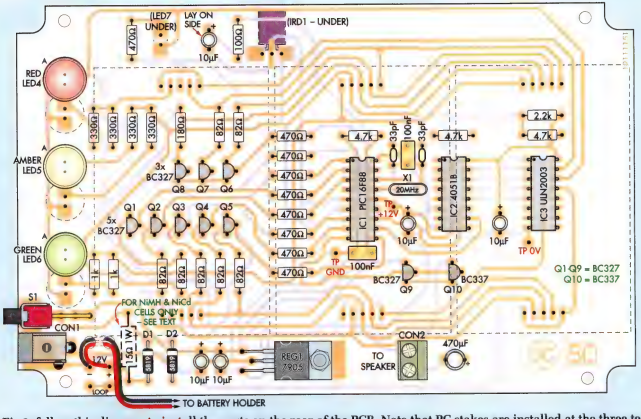


Fig.3: follow this diagram to install the parts on the rear of the PCB. Note that PC stakes are installed at the three test points (TP) and at the LED4-LED6 positions. LEDs4-6 are then mounted proud of the PCB, as described in the text.

sistors are used. The green LEDs are much brighter for the same current and so the current in these is further reduced using 1kΩ resistors. A 470Ω current limiting resistor is used for blue LED7. Dimming is achieved by switching the displays off for part of the normal 2.5ms on period.

Infrared receiver

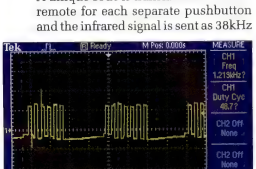
Infrared receiver IRD1 receives the signal sent by the SparkFun remote. A unique code is transmitted from the remote for each separate pushbutton and the infrared signal is sent as 38kHz bursts, using coding that is known as Pulse Distance Protocol. For further information about the infrared coding, refer to the 9-Channel Infrared Remote Control article in the September 2015 issue – see **www.siliconchip.com.au/Issue/2015/September**

IRD1 includes an amplifier and a demodulator. Demodulation removes the 38kHz component and IRD1's pin 1 output goes low when it is receiving the pulsed 38kHz signal and high in the absence of signal.

IC1 decodes the incoming signal from IRD1 and reacts to any valid coded signal. So, for example, when the "A" button is pressed on the remote control, the speaker will be driven. This alarm signal comprises a 1.22kHz signal modulated at 200Hz.

This 1.22kHz signal is produced by a PWM (pulse width modulated) output at pin 9 of IC1. The signal is buffered using complementary transistors Q9 & Q10 and AC-coupled to the loudspeaker via a 470µF capacitor. The volume is set by the actual pulse width of the signal, with a 50% duty cycle giving maximum volume.

The accompanying scope waveform shows the signal across the loudspeaker when sounding an alarm at maximum volume. The alarm signal comprises six or seven cycles of the 1.22kHz tone modulated on and off at a 5ms rate.



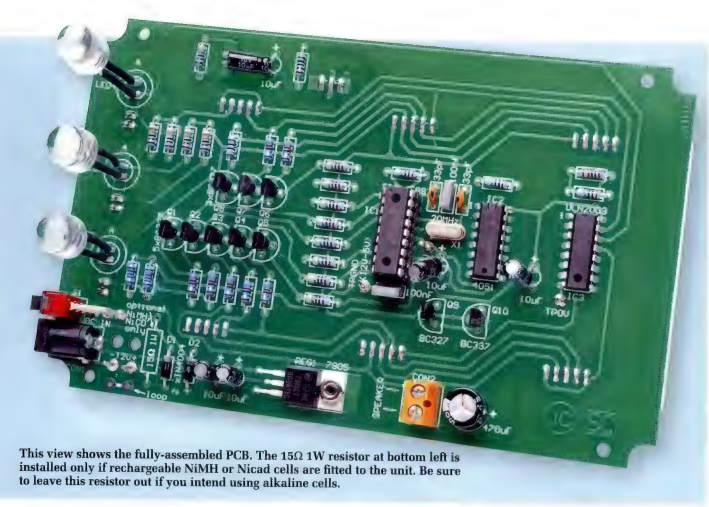
This oscilloscope grab shows the modulated 1.22kHz signal across the loudspeaker when the alarm is sounding at full volume.

Clock signal

IC1 runs at 20MHz using crystal X1, to ensure timekeeping accuracy. 20MHz is used in preference to a lower frequency such as 4MHz, as the software requires considerable processing to drive the displays, update the timer and decode the infrared signal without faltering.

The battery voltage is monitored at analog input AN1 (pin 18) of IC1, via a 2.2kΩ and 4.7kΩ resistive divider. IC1 converts the monitored battery voltage to a digital value and compares this against the low-battery voltage threshold of 8.8V. If the battery voltage is low, it turns on LED7 continuously, at a low level. LED7 also flashes when IC1 receives a valid signal from the remote control.

As previously noted, the circuit can be run from a 12V DC plugpack and/or a battery comprising eight AA cells. They are connected to power switch S1 via Schottky diodes D1 & D2. These



This view shows the fully-assembled PCB. The 15Ω 1W resistor at bottom left is installed only if rechargeable NiMH or Nicad cells are fitted to the unit. Be sure to leave this resistor out if you intend using alkaline cells.

diodes provide reverse polarity protection and isolate the 12V plugpack supply from the AA cells. D2 could be a standard 1N4004 instead but a Schottky diode is specified to avoid any mix up when installing D1 & D2.

A 15Ω 1W resistor can be fitted between the battery and the 12V supply following D2 to allow trickle charging of rechargeable NiMH or Nicad cells. This resistor must be omitted if alkaline cells are used.

REG1 is a 7905 negative regulator which provides the 5V supply to IC1. As shown, 10µF supply decoupling capacitors are included at the input and output of this regulator while the supply to IC1 (pin 14) is further decoupled with a 100nF capacitor.

Building it

Building the Speech Timer is easy since all the parts are mounted on a double-sided PCB coded 19111151 (162.5 x 102mm). This is housed in a UB2 plastic case (197 x 113 x 63mm), with the lid replaced by a red Perspex or acrylic transparent sheet. Alternatively, a cut-out can be made in the lid that comes with the case and a transparent window fitted to this cut-out.

As shown on Figs.3 & 4, parts are mounted on both sides of the PCB. Most of the parts are mounted on the "rear" of the PCB, while the "front" carries the three 7-segment LED displays (DISP1-DISP3) plus five other parts, including the infrared receiver (IRD1).

Begin the Speech Timer assembly by installing the parts on the rear of the PCB – see Fig.3. The resistors can go in first, taking care to ensure that the correct value goes in each location. Table 2 shows the resistor colour codes but you should also check each one using a digital multimeter (DMM) before soldering it into position.

Note that the 15Ω 1W resistor is

Table 2: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	3	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1	2.2kΩ	red red red brown	red red black brown brown
❑	2	1kΩ	brown black red brown	brown black black brown brown
❑	9	470Ω	yellow violet brown brown	yellow violet black black brown
❑	4	330Ω	orange orange brown brown	orange orange black black brown
❑	1	180Ω	brown grey brown brown	brown grey black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	7	82Ω	grey red black brown	grey red black gold brown
❑	1	15Ω	brown green black brown	brown green black gold brown

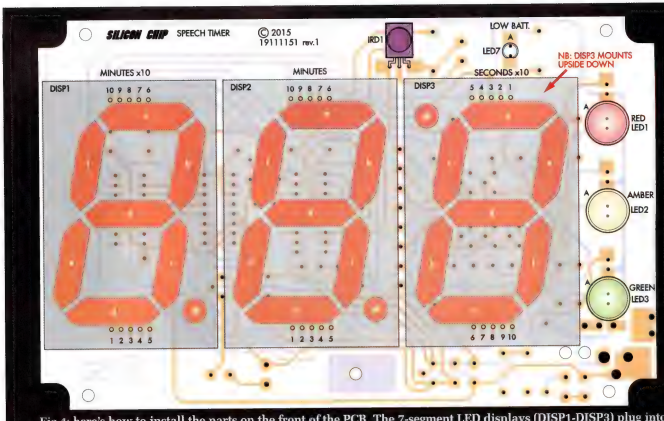


Fig.4: here's how to install the parts on the front of the PCB. The 7-segment LED displays (DISP1-DISP3) plug into 5-way SIL socket strips and DISP3 must be installed upside down. IRD1, LEDs1-3 & LED7 are all mounted proud of the PCB, as described in the text (see also Figs.5 & 6).

only installed if you intend to run the Speech Timer using NiMH or Nicad cells. DO NOT install this resistor if you will be using alkaline cells.

Diodes D1 & D2 can go in next, followed by an 18-pin DIL socket for IC1. Make sure that these parts are all orientated correctly before soldering them to the PCB. IC2 & IC3 can then be fitted and these parts can either be directly soldered in place or mounted via 16-pin sockets.

Regulator REG1 is next on the list. As shown, this part mounts horizontally with its leads bent down through 90° to fit into the allocated holes. Fasten the regulator's tab to the PCB using an M3 x 6mm screw and nut before soldering its leads. Don't solder the leads first – you could crack the PCB tracks or pads as the tab is fastened down if you do.

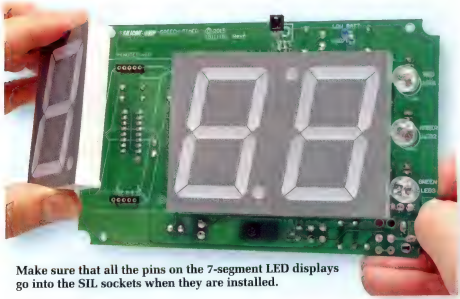
Crystal X1 can now be fitted; it's mounted just to the right of IC1 and can go in either way around. That done, install PC stakes at the 12V supply positions near CON1 (to connect the battery leads), at the TP 12V, TP GND and TP 0V positions and at the LED4-LED6 positions.

The next step is to mount transistors Q1-Q10. Note that Q1-Q9 are all BC327s, while Q10 is a BC337. Make sure that the BC337 goes in the Q10 location. Make sure also that the tops of the transistors sit no more than 10mm above the PCB, otherwise they will later foul the AA cells (if fitted).

Now for the capacitors. Install these as shown, making sure that the electrolytic types are correctly orientated. **Note that the 10µF electrolytic capacitor at top left must be installed with its side flat against the PCB** (see photo), so that it will later clear the AA cells.

Follow with the DC socket (CON1), the screw terminal block (CON2) and switch S1. Be sure to install CON2 with its wire entry side towards REG1.

That completes the assembly on the rear side of the PCB apart from



Make sure that all the pins on the 7-segment LED displays go into the SIL sockets when they are installed.

Take care to ensure that the LEDs and the three 7-segment displays are all orientated correctly. Note that DISP3 is installed upside down in order to obtain a flashing colon. The diode test facility on a DMM can be used to sort out the LED colours (see text).

LEDs4-6. Leave these off for the time being.

Front PCB assembly

Fig.4 shows the layout on the front of the PCB. The first step is to install six 5-way SIL (single in-line) socket strips to mount the three 7-segment displays. These socket strips are cut from three 14-pin IC sockets and the cut edges filed to a smooth finish before installation. Be sure to push the socket strips all the way down so that they sit flush against the PCB before soldering their pins.

Next, cut the pins on each 7-segment display to 4mm in length using a pair of side-cutters. That's best done by first cutting a 4mm-wide length of cardboard and then holding this against the pins as they are trimmed. Don't install the displays just yet though. That's done after the remaining parts have been installed on this side of the PCB.

LEDs1-3 can go in first. These must all be orientated correctly, with the longer anode leads going to the "A" position, and they must be mounted on 12mm lead lengths.

These LEDs all come with clear lenses, so you will have to sort out which is red, which is amber and which is green. That's easily done by using the diode test facility on a DMM. Each LED should light when the DMM's probes are connected with the correct polarity (ie, red to anode, black to cathode).

Use a 12mm-wide cardboard spacer to set the LED heights. It's just a matter of sliding the spacer between the leads, pushing the LED down onto the spacer and then lightly tack soldering one of the leads. The other lead can then be soldered, after which extra solder can be added to the first lead.

Once all the LEDs are in place, tin their leads from the PCB to just shy of the plastic lenses. This will stiffen the leads and ensure that the LEDs cannot be pushed in from the front panel when the PCB is installed in the case.

Alternatively, before installing the LEDs, fit their leads with 12mm lengths of 1mm-diameter heatshrink sleeving (this will also eliminate the need to cut a cardboard spacer).

LED7 is fitted in similar fashion on 13mm-long lead lengths (Fig.5). Once again, its anode lead is the longer of the two and there's a flat side on the plastic body adjacent to the cathode.

Now for the infrared receiver. Fig.6 shows how this part is mounted. First, bend its leads down through 90° exactly 5mm from its body, then fit it to the PCB on 15mm vertical lead lengths (use a 15mm-wide cardboard spacer to set this). It's a good idea to lightly tack solder one lead first, then check that all is correct before soldering the remaining two pins and then refreshing the first pin with extra solder.

Installing LEDs4-6

The PCB can now be flipped over

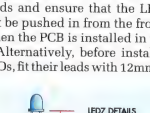


Fig.5: LED7 is stood off the PCB on 13mm long leads, as shown here.

Fig.6: the mounting details for IRD1. Its body sits 15mm above the PCB.

This view shows the case lid with the red Perspex window in place and the holes drilled and cut for the LEDs & IRD1.

and LEDs4-6 installed. These LEDs must be installed so that their plastic bodies are 34mm above the PCB and to do that, it's necessary to solder their leads to tinned copper wire risers.

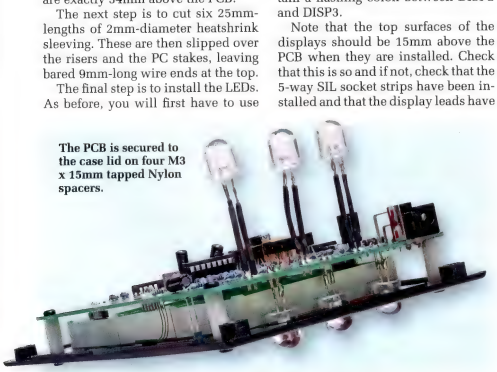
The first step is to fit 35mm lengths of 1mm-diameter tinned copper wire to the six PC stakes in the LED locations. Make sure that these wires are perfectly straight and vertical. You can straighten tinned copper wire by clamping one end in a vice and then stretching it slightly by pulling on the other end with pliers. Once the risers are in place, cut a 34mm-wide cardboard strip and use this as a guide to trim the wire lengths so that their ends are exactly 34mm above the PCB.

The next step is to cut six 25mm-lengths of 2mm-diameter heatshrink sleeving. These are then slipped over the risers and the PC stakes, leaving bared 9mm-long wire ends at the top.

The final step is to install the LEDs. As before, you will first have to use the diode test facility on a DMM to sort out the colours. That done, install LED4 by first feeding its leads down the heatshrink tubing. Push it all the way down until its body contacts the tops of the risers, then solder each lead to its riser between the heatshrink and the LED's body. Repeat this procedure for LEDs5 & 6, taking care to ensure that the LEDs are correctly orientated.

Finally, complete the PCB assembly by plugging in the three 7-segment displays (DISP1-DISP3). There's just one thing to watch out for here: **DISP3 must be fitted upside down, so that its decimal point is at top left (see Fig.4).** As explained earlier, that's done to obtain a flashing colon between DISP2 and DISP3.

Note that the top surfaces of the displays should be 15mm above the PCB when they are installed. Check that this is so and if not, check that the 5-way SIL socket strips have been installed and that the display leads have all been correctly trimmed to 4mm, as described earlier.



The PCB is secured to the case lid on four M3 x 15mm tapped Nylon spacers.

Battery holder connections

As shown on Fig.3, the leads from the battery holder are looped through two stress relief holes in the PCB. They are then soldered to the supply PC stakes, with the red wire going to the positive terminal and the black wire to the negative terminal.

If you are using two 4-AA holders instead of a single 8-AA holder, it will be necessary to connect the two holders in series. That's done by connecting the red wire from one holder to the black wire from the second holder. The easiest way to do that is to feed these red and black wires through the two stress relief holes and connect them to the two terminals marked LOOP on the PCB. The remaining red and black wires are then also fed through the stress relief holes and connected to the 12V PC stakes as before (enlarge the stress relief holes if necessary).

Case preparation

The PCB assembly can now be put aside while you drill and cut the necessary holes in the case. As mentioned previously, the lid can be replaced with either a Perspex or acrylic transparent red sheet (195 x 110mm). Alternatively, you can use the lid supplied with the box and make a cut-out (fitted with a transparent window) for the 7-segment display.

The first step is to download the drilling template file (in PDF format) from the SILICON CHIP website (go to **www.siliconchip.com.au** and search for the project). Print this template out, then cut out the individual sections and attach them to the case using adhesive tape.

If you are completely replacing the lid, then you don't have to make the rectangular cut-outs for the displays or for infrared receiver IRD1, since they simply sit behind the transparent panel. However, 3mm holes will be required for the four corner mounting positions where it attaches to the box pillars (see the template).

Conversely, if you are using the lid, you will need to make the rectangular cut-outs.

In either case, it's best to use a pilot drill (eg, 1mm) to start the holes and then enlarge them to size. All the small holes are 3mm diameter, while the larger holes are 10mm diameter.

The larger holes should be drilled out to about 4mm and then carefully reamed to the correct size. It's best to ream one of these larger holes first, so that one of the 10mm LEDs just fits. You then push the reamer into the hole as far as it will go and wind a ring of tape around the shaft (on the outside). The remaining five holes can then all be reamed out until the tape stops the reamer from going any further.

Be careful when drilling or reaming Perspex, by the way. It can easily crack if the drill or reamer is forced into the hole.

If using the original lid, the rectangular cut-outs can be made by drilling a series of small holes inside the perimeter, then knocking out the inside piece and filing to shape. Make sure that the large cut-out is exactly the same size as the Perspex window so that the latter is a tight fit. The window can be secured in place using a few spots of contact adhesive.

The rear of the box has to be drilled for LEDs4-6, while a pattern of 5mm holes is also required for the loudspeaker. In addition, a hole is required in the righthand end of the case to provide access to the DC socket and on/off switch (these holes go in the end of the case adjacent to the 10mm LED holes).

Front-panel label

The front-panel label is available in PDF format on the SILICON CHIP website. It's just a matter of downloading it and printing it out onto an A4 sized synthetic Dataflex or Dataplex sticky label (see panel). This label can then be attached to the lid and the holes cut out using a sharp hobby knife.

Alternatively, you can print out a paper label and attach this to the lid using double-sided tape.

An additional label (Fig.1) shows the function of each of the buttons on the handheld remote and this is affixed to top panel of the case (see photos).

Final assembly

Now for the final assembly. The first job is to mount the PCB assembly on the lid (or Perspex panel) using M3 x 15mm spacers and eight M3 x 6mm machine screws. Once that's done, the AA cell holder can be secured inside the case. This is mounted against the base of the box and is secured to the top panel using a No.4 x 9mm self-tapping screw.

The view inside the completed prototype. The battery holder is secured to the top of the case using a No.4 x 9mm self-tapping screw that goes into a slot at one end of the holder's plastic moulding.

Drill a 3mm hole for this screw in the top panel exactly 77mm from the righthand side of the case and 38mm from the front (as measured without the lid). The self-tapping screw is then fed through this hole and goes into one of the slots in the end of the cell holder's plastic moulding.

The last part to go in is the loudspeaker. It's just a matter of securing it in place on the rear panel (ie, the base of the box) using a suitable adhesive such as super glue, contact adhesive or neutral-cure silicone. Smear the glue around the perimeter of the speaker frame, then centre it over the holes made in the base of the box and wait for the adhesive to set. The speaker is then connected to the 2-way screw terminal block on the PCB using figure-8 cable.

Testing

Now for the smoke test. Check that IC1 is out of its socket, then apply power and check that the voltage between TP +12V and TP GND (ie, between pins 14 & 5 of IC1's socket) is 5V. Note that this reading can be anywhere between 4.75V and 5.25V, depending on the regulator.

If this is correct, switch off and install IC1 into its socket, taking care with its polarity. That done, reapply power and check that the displays show 0:0 but with DISP1 unlit. This unlit digit is due to the leading zero blanking that's incorporated in the tim-

Dataflex/Datapol Labels

(1) For Dataflex labels, go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_60&products_id=335
(2) For Datapol labels go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_55&products_id=326

Parts List: Speech Timer

1 double-sided PCB, code 19111151, 162.5 x 102mm
1 front panel label, 195 x 110mm
1 remote control button function label, 23 x 64mm
1 UB2 plastic case, 197 x 113 x 63mm
1 9-button IR remote control (Little-Bird Electronics, SparkFun SF-COM-11759)
1 CR2025 3V alkaline cell
1 141 x 68 x 3mm transparent red acrylic or red Perspex sheet (or 195 x 110mm – see text)
1 PCB-mount vertical slider switch (Altronics S2071) (S1)
1 8-AA cell holder or 2 x 4-AA holders (optional)
8 AA alkaline, NiMH or Nicad cells (optional)
1 12V DC 400mA plugpack (optional)
1 2.5mm or 2.1mm PCB-mount DC socket (CON1)
1 2-way screw terminal block, 5.08mm pitch (CON2)
1 76mm 8Ω loudspeaker
1 20MHz parallel resonant crystal (X1)
1 DIP18 IC socket
3 DIP14 IC sockets cut into 6 x 5-way SIL socket strips
4 M3 x 15mm tapped Nylon spacers
9 M3 x 6mm screws
1 M3 nut
1 No.4 x 9mm self-tapping screw (when 8-AA cell holder is used)
1 100mm length of medium-duty figure-8 wire
11 PC stakes
1 210mm length of 1mm-dia. tinned copper wire
1 150mm length of 2mm-dia. heat-shrink tubing

Semiconductors

1 PIC16F88-I/P microcontroller programmed with 1911115A.hex (IC1)
1 4051B single-pole 8-way analog switch (IC2)
1 ULN2003 7-Darlington array (IC3)
1 7905 negative 5V regulator (REG1)
9 BC327 PNP transistors (Q1-Q9)
1 BC337 NPN transistor (Q10)
3 58mm 7-segment displays (Jaycar ZD-1850) (DISP1-DISP3)
2 waterclear red 2000mcd 10mm LEDs (LED1,LED4)
2 waterclear amber 9000mcd 10mm LEDs (LED2,LED5)
2 waterclear green 13000mcd 10mm LEDs (LED3,LED6)
1 3mm blue LED (LED7)
1 TOSOP4136 38kHz IR receiver or similar (IRD1)
2 1N5819 1A Schottky diodes (D1,D2)

Capacitors

1 470µF 25V PC electrolytic
5 10µF 16V PC electrolytic
2 100nF MKT polyester
2 33pF ceramic

Resistors (0.25W, 1%)

3 4.7kΩ	4 330Ω
1 2.2kΩ	1 180Ω
2 1kΩ	1 100Ω
9 470Ω	7 82Ω

1 15Ω 1W 5% (optional – see text)

er. DISP1 should light up only when it is required to display anything other than zero.

Check that the blue acknowledge LED flashes when using the infrared remote. Further operation can then be tested using the remote control, as set out in the following section.

A hole is cut in the righthand end of the case to provide access to the DC socket & on/off switch.

Remote control

We've already briefly mentioned the SparkFun remote and its button functions. Let's now take a look at the 5-button array below the A, B & C buttons and describe how they control the Speech Timer.

The left arrow button is for Reset – it stops and resets the clock timer to zero. In this state, the Up and Down buttons can be used to scroll up or down through the preset timer selections. These selections include the 0:0 setting and the presets 1-2, 2-3, 3-5, 5-7, 10', 15' and so on up to 90' (the ['] symbol indicates minutes).

Pressing the right arrow button (Start) starts the timer running. It starts with 0:0 displayed and the colon flashing at a 1-second rate.

The central "O" button is the Pause button and is used to stop the clock, so that it ceases incrementing. When paused, the colon stops flashing to indicate that it is in this mode.

Pausing is useful for stopping the Speech Timer after the contest so that the overall time can be read off the display (and written down if necessary). The timer can then resume from that time by pressing the Start button or reset back to zero by pressing the Reset (left arrow) button.

Note that there is only a single "seconds" digit on the timer display and this normally only shows the tens of seconds. It increments by one each 10 seconds when the clock is running.

The exact seconds value can be viewed by pressing the Up or Down button. For example, let's say that the display shows 12:4 (ie, 12 minutes and 40 seconds). Pressing the Up or Down button then causes the display to show the exact number of seconds, eg, 43" (ie, 43 seconds). This was only partially displayed as the 4 in the 12:4 display.

Note that the ["] after the 43 is the symbol for seconds and the exact number of seconds is only displayed while the Up or Down button is held pressed.

Note also that the seconds only show when the timer clock is running or when it is paused but not when reset. The seconds are reset to zero when the unit is reset (left arrow button) and the Up and Down buttons are

A pattern of 5mm holes is drilled in the rear panel for the loudspeaker, while an artwork showing the remote control functions is attached to the top panel.

then instead used to select one of the timer presets.

Additional buttons

The SparkFun remote's power button is used to adjust the brightness of the 7-segment displays (DISP1-DISP3). These displays can be dimmed up or down, with the dimming direction changed each time the button is pressed. Pressing and holding the button begins dimming in either direction.

The remote's "B" button is used to independently adjust the Brightness of the indicator LEDs in the same way as the power button.

The "A" button serves two functions: (1) to manually sound the alarm and (2) to set the volume. If this button is pressed for more than five seconds, it operates as a volume control. After this time, the normally modulated alarm tone becomes continuous, indicating that the unit is in volume setting mode. The "A" button then has to be released and repressed within 1.25 seconds. When that's done, the modulated alarm tone is restored and the volume begins to change.

If the volume is changing in the wrong direction, it's just a matter of releasing and repressing the "A" button once more. The volume will then change in the opposite direction. The volume will continue to change for long as you continue pressing the button until it reaches its maximum or minimum level.

Releasing the "A" button for more than 1.25s exits the volume setting mode and this will be indicated by a brief "chirp" from the loudspeaker. The alarm (A) button will then operate as normal unless pressed again for longer than five seconds.

The "C" button cycles through the warning LED indicators, starting with all LEDs off and then lighting the green LED, then the amber LED and finally the red LED in a cyclic fashion for each press of the button.

Finally, note that the timer presets, display brightness and volume settings are stored in EEPROM and are retained when power is switched off. This saves you from having to re-enter the setting each time power is reapplied.

That's it – your Speech Timer is ready for action. **SC**

Using The Speech Timer In Count-Down Mode

Normally, all times set for the Speech Timer, whether preset or manual, are in Count Up mode, eg, a 10-minute speech will start from zero and count up to the set time, at which point the red warning LED will come on. But the counter will continue to run after that and if the speech was being given at a Toastmasters' meeting, there is a risk of disqualification if the speech runs for another minute or more (whatever the rule).

In addition, the Speech Timer can also operate in Count Down mode. In this case, for a 10-minute speech (say), the Speech Timer will start at 10:0 minutes and then count down in 10-second decrements to zero. At zero, the buzzer will also sound briefly.

To access the Count Down mode, you simply press the Up button on the remote repeatedly until you get a display of 0:0. Further presses of the Up button then increase the timer setting from 0:0 to 0:1 and so on up to 99:5 (ie, 99 minutes and 50 seconds).

Once the timer setting is above 0:0, the remote's Down button can be used to decrease the setting if necessary.

In operation, the Up and Down buttons increase/decrease the timer setting in single step with each button press. Alternatively, holding down a button will cause the timer value to rapidly change up or down.

Once the timer value has been set, pressing the Start (right arrow) button) will cause the timer to start counting down to 0:0. When it reaches 0:0, the timer will stop and the buzzer will automatically sound for 2.5s. The previous Count Down timer setting can then be restored by pressing the Reset (left arrow) button.

Warning LEDs

The warning LEDs can also be preset. That's done simply by selecting a warning LED with the remote's "C" button. The selected LED can then be programmed to turn on at a certain time during the count down using the Up & Down buttons.

You can program each warning LED but note that you need to select the next LED using the "C" button before changing the time setting. Note also that, during the count down, you need to have the green LED light before the amber LED which in turn lights before the red LED. This means that it's best to program the green LED first, followed by the amber LED and then the red LED, each with a progressively lower time setting.

The warning LED programming an be cancelled by setting the timer to 0:0 and then cycling through each LED with the "C" button.

Restoring count up timing

Pressing the Down button when the timer is at 0:0 re-selects the preset periods, starting with 90', then 80' etc. This resets the Speech Timer to function as a Count Up timer and the presets can then be selected using the Up and Down buttons.

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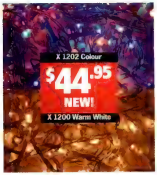
Issue: December 2013

Festive Gift Guide



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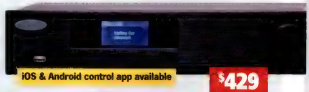

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Type	Part	Normally	5m Roll
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RGB IP65 Outdoor	X 3214A	$64.95	$55

Add-Ons	Part	ea
Controller & Remote	X 3217	$14.95
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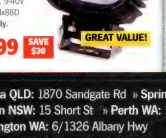

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(SC Oct' 2015) An easy-to-build Arduino project which will let you take your own electrocardiogram (ECG) and display it on a laptop PC. The software lets you read, display, save and print the electrical waveform generated by your heart – or anyone elses. Requires Arduino UNO.

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(SC Dec '10 - Mar '11) Based on a PIC micro, this project can log data to an SD card (sold separately). It can read from many types of digital & analog sensors. A real-time clock time-stamps the data. PC host program allows you to configure sensors, change settings and charge the battery via USB (2 x AAA, not included).

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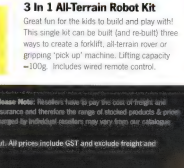

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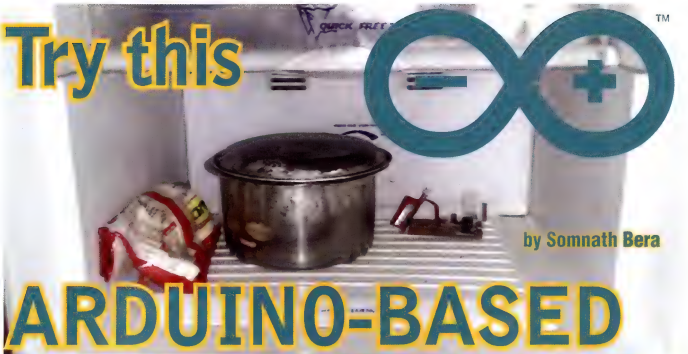


Try this

by Somnath Bera

ARDUINO-BASED FRIDGE MONITOR AND DATA LOGGER

Monitor the temperature and humidity in your refrigerator (or elsewhere) remotely with this Arduino-based device. It can also log these parameters over time so you can see how much the temperature and humidity vary as the compressor cycles on and off, how often the defrosting cycle occurs, how often the door is opened and so on.

This remote sensor/data logger is based on a minimal Arduino-compatible circuit. As is typical for Arduinos, it uses an Atmel AVR ATmega328 microcontroller.

You could use a pre-built Arduino board such as the original Uno, the Freetronics Eleven or the Leostick but the simpler circuit also has the advantage of reducing power consumption and therefore extending battery life.

With the specified battery (6 x 2Ah NiMH AA cells), the logger will run for roughly two days continuously.

The time, temperature and humidity are shown on a remote backlit LCD which can be up to 100m away from the logger (depending on intervening obstacles, antenna size etc). This data is also logged to a file on a microSD card every five seconds along with a time stamp.

This would be a good project for relative beginners, especially those interested in learning how to use Arduino boards, since it involves relatively few components and uses several pre-built modules.

Circuit description

There are two circuits for this project. The first, shown in Fig.1, is the sensor/logger/transmitter unit comprising the ATmega328 micro, AM2302/DHT22 single wire temperature/humidity sensor, 433MHz transmitter and MicroSD module for data storage.

A 16MHz crystal is used as the instruction clock source so the micro can keep time with reasonable accuracy. The AM2302 or DHT22 sensor (TS1) is connected to input pin 5 of IC1 (digital input #3) with a 1kΩ pull-up.

The Arduino software decodes the digital signals from this sensor to get the temperature and humidity readings. These are then sent to 433MHz transmitter module TX1 from pin 4 (digital output #2).

This data is also periodically logged to the microSD card via breakout board SD1. This is driven from IC1's SPI interface consisting of pins 16 (slave select), 17 (data; master out, slave in), 18 (data; master in, slave out) and 19 (serial clock). The card detect pin is not used as the card is not normally

inserted or removed during operation.

SD cards require a 2.7-3.3V supply and the breakout board we have specified contains an onboard 3V 150mA regulator which runs from 5V. We aren't using the 3V supply elsewhere so that pin is left unconnected. The breakout board also has a 74HC4050 level shifter IC onboard to translate the 5V signals from IC1 to a level suitable for the SD card (ie, 0-3V). Output signals from the SD card go directly to IC1 as its inputs will sense 3V as a high level when running from a 5V supply.

The micro's own power supply is basic, using just a 100Ω series resistor and 5.1V zener diode to regulate the ~7.2-9V supply from the six AA batteries to 5V. A 3-terminal regulator could be substituted for reduced operating current. Switch S1 turns power to the circuit on and off.

Momentary push-buttons S2 and S3 are used to set the time for logging. The remote receiver unit shows the time being transmitted by the logger so it's simply a matter of pressing these buttons to increment the hour/minute reading until the time on the receiver is correct. The log entry time stamps will then be correct. However note that the date at power-up is hard-coded into the Arduino sketch so the micro will need to be re-programmed each time the logger is to be used for the date stamps to be correct.

Pushbutton S4 is used to halt logging and the unit must be power-cycled to resume. Each time the unit powers up, it creates a new file on the SD card to which log entries for that session are written. The temperature and humidity is logged every five seconds.

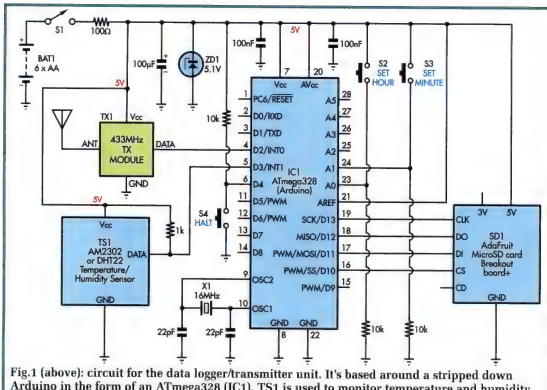


Fig.1 (above): circuit for the data logger/transmitter unit. It's based around a stripped down Arduino in the form of an ATmega328 (IC1). TS1 is used to monitor temperature and humidity and data is transmitted in real-time using 433MHz module TX1. Data is simultaneously logged to the microSD card via SD1.

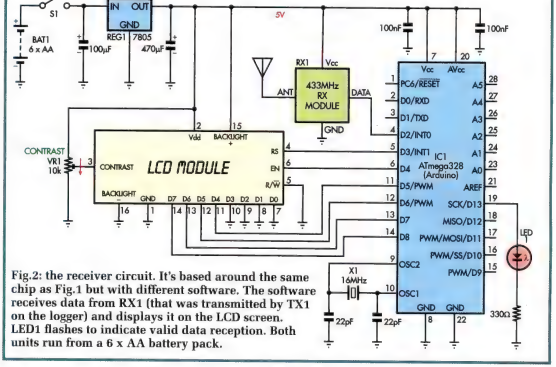
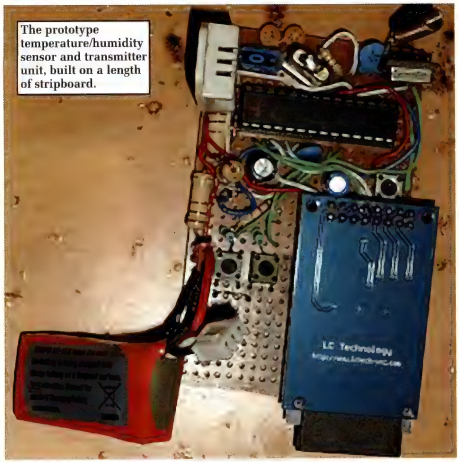


Fig.2: the receiver circuit. It's based around the same chip as Fig.1 but with different software. The software receives data from RX1 (that was transmitted by TX1 on the logger) and displays it on the LCD screen. LED1 flashes to indicate valid data reception. Both units run from a 6 x AA battery pack.

Alternative microSD interface

SparkFun also make a similar microSD card interface, however it is a full-sized Arduino shield. This would be handy if you are planning to build your temperature/humidity logger using an actual Arduino board such as the Freetronics Eleven. However it will be larger and consume more power.

The only change necessary to use the SparkFun shield is to connect pins D8 and D10 together. That's because the



The prototype temperature/humidity sensor and transmitter unit, built on a length of stripboard.

SparkFun shield uses D8 as the Card Select pin. D10 is more traditional as this corresponds to the micro's hardware slave select pin, however in practice any digital I/O can be used for this purpose. Our circuit doesn't use D8 so joining them should not cause any problems.

One advantage of using the SparkFun microSD card shield is that it contains an 11 x 12 prototyping area along with pads to make connections to each of the Arduino pins. Most or all of the required extra components will fit there, making for a neat finish.

Receiver unit

The receiver unit, (Fig.2) is also based around an ATmega328 microcontroller. The data stream from a 433MHz receiver unit is connected to pin 4 (digital input #2) and the micro drives a 16x2 alphanumeric LCD module (LCD1) in 4-bit mode. It does this via digital outputs D5-D8 (pins 11-14) for data and using digital output #3 (pin 5) to control the reset pin and digital output #4 (pin 6) to control the enable pin.

The R/W pin of the LCD module is tied to ground as there's no need to read data from it. The backlight LED circuit is connected directly across the 5V supply while a 10kΩ trimpot provides contrast adjustment by varying the negative bias voltage at pin 3, relative to the positive supply, between 0 and -5V.

IC1 waits to receive valid data from RX1 and when it does, it updates the LCD to show the time (as reckoned by the logger), temperature (in degrees Celsius), relative humidity percentage and status. At the same time, LED1

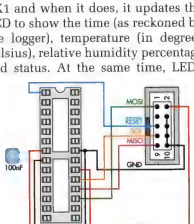


Fig.3: if you want to program an ATmega328 chip using an in-circuit serial programmer (ICSP), here is how to make an adaptor board. Note the orientation of the 10-way IDC socket which is shown in top view. You may need to add a crystal and load caps between pins 9 & 10 of the IC socket to re-program a chip that has already been programmed (see text).

is flashed to show that valid data has been received.

Logging other parameters

If you wanted to attach other sensors to the Arduino you could do so – it has plenty of spare analog and digital pins. You would have to modify the transmitter "sketch" software, to sample data from the new sensor and include it in the transmitted packets and logfile. You would also need to modify the receiver sketch to decode and display the extra data (unless you simply wanted to log it).

We won't go into great detail on how to do that here but that's the great thing about systems like Arduino – you can download the source code for this project and modify it as much as you want. If you don't know how to program an Arduino, there are plenty of books and internet pages that explain how to do so and also internet forums where you can ask questions and get help.

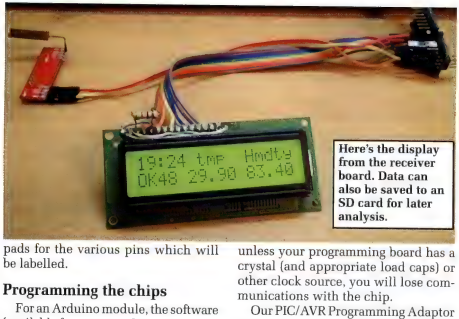
Construction

Our prototypes were built on Veroboard using point-to-point wiring – see the adjacent photo. There are various different types of protoboard available including an "IC prototyping board" (which goes under various names) that mimics the connection pattern used on solderless breadboard. That would probably be a good choice for this project although a "donut board" (just copper rings on a 0.1" grid) would work too.

Construction for both units is similar. Luckily neither circuit is too complex and most of the "heavy lifting" is done by pre-built modules. In both cases, start by soldering in the socket for IC1. Add the crystal, ceramic capacitors and pull-up/pull-down resistors across the appropriate pins. The next step is to mount the various modules, pushbuttons and switches in convenient locations and then run insulated wires connecting to their pins back to the appropriate IC pins as shown in the relevant circuit diagram.

Finally, wire up the power supply and prepare to connect the battery.

If you're basing your unit on a pre-built Arduino module, construction is a bit easier. If not using the microSD card shield with prototyping area, or for the receiver unit, you can use a prototyping shield which simply plugs into the Arduino board. Like the microSD card shield, these also provide connection



Here's the display from the receiver board. Data can also be saved to an SD card for later analysis.

pads for the various pins which will be labelled.

Programming the chips

For an Arduino module, the software (available from www.siliconchip.com.au) can then be uploaded using a USB cable and the free Arduino IDE software from www.arduino.cc/en/Main/Software

In this case you will be compiling and uploading the .ino "sketch" file via the IDE, once you have selected the correct target board and established communications.

However if you are building the minimal design you will need an Atmel AVR in-circuit programmer along with a 28-pin programming rig. AVR ICSP adaptors are available from websites like Ali Express and eBay starting at less than $2. Just search for "avr programmer". You may be supplied with suitable software; if not, use software such as avrdude-gui (http://sourceforge.net/projects/avrdude-gui/) or PonyProg (www.lancos.com/prog.html).

You will also need a programming adaptor for the ATmega328. You could use our PIC/AVR Programming Adaptor board from the May and June 2012 issues, or you could build one on a small piece of Veroboard with a 28-pin socket (ideally, ZIF) plus a 2x5 pin header. The required circuit is shown in Fig.3.

Note that there are a couple of tricks when programming an AVR using the ICSP method. One, you may need to set the "fuses" as a separate step to uploading the hex file. You can determine the correct fuse settings for your chip to run an Arduino sketch here: www.engbedded.com/fusecalc

Secondly, you should set the fuses AFTER uploading the hex file because once you do, the chip will switch to running off the external crystal and unless your programming board has a crystal (and appropriate load caps) or other clock source, you will lose communications with the chip.

Our PIC/AVR Programming Adaptor board has a selectable clock source for this sort of situation (see that article for more details) although if using your own adaptor, you could simply solder a crystal and pair of caps to pins 9 and 10 of the socket as shown in Figs.1 & 2.

Alternatively, if you don't have an AVR in-circuit serial programmer, you could get a universal programmer such as the MiniPro TL866CS and use the supplied software. These are available for around $40 on Ali Express and ebay and can program just about any programmable chip including most PICs and AVRs.

Powering it up

Regardless of how you programmed the chips, plug in the receiver unit chip and switch it on. The LCD backlight should come on but not much else will happen as the transmitter is not running yet.

If using the logging functionality, insert a blank microSD card into the receiver unit before switching it on. Once both units are on, after a few seconds you should see a display on the receiver LCD which will update periodically with new temperature and humidity data.

You can then use the pushbuttons on the transmitter/logger unit to set the correct time. After that it's simply a matter of placing the transmitter logger in the fridge or whatever else you want to monitor and observe the readings on the receiver LCD. You can then leave the logger to do its thing, retrieve it later, press S4, switch it off and remove the microSD card to check the logged data on a PC. SC

Parts list – Arduino-based Temperature/ Humidity Monitor

Logger/transmitter unit

1 piece Veroboard/protoboard/stripboard
1 28-pin narrow IC socket
1 AdaFruit industries MicroSD card breakout board+ (SD1) **OR**
1 SparkFun MicroSD shield (SD1) (see text)
1 AM2302 or DHT22 temperature & humidity sensor (TS1)
1 433MHz transmitter module (TX1)
1 172mm length of stiff insulated wire (antenna for TX1)
1 six AA-cell battery holder
1 toggle or slide switch (S1)
3 momentary pushbutton switches (S2-S4)
1 16MHz crystal (X1)

Semiconductors

1 ATmega328 microcontroller programmed with **remote_datalogger_with_time_set.ino/hex**
1 5.1V 1W zener diode (ZD1)

Capacitors

1 100µF 16V electrolytic
2 100nF ceramic
2 22pF ceramic

Resistors (0.25W, 5%)

3 10kΩ 1 1kΩ 1 100Ω

Receiver unit

1 piece Veroboard/protoboard/stripboard
1 28-pin narrow IC socket
1 16x2 alphanumeric backlit LCD module (LCD1)
1 433MHz receiver module (RX1)
1 172mm length of stiff insulated wire (antenna for RX1)
1 six AA-cell battery holder
1 toggle or slide switch (S1)
1 16MHz crystal (X1)

Semiconductors

1 ATmega328 microcontroller programmed with **fridge_temp_receiver_lcd_with_data_logger_time_set.ino/hex**
1 7805 5V regulator (REG1)
1 LED (LED1)

Capacitors

1 470µF 10V electrolytic
1 100µF 16V electrolytic
2 100nF ceramic
2 22pF ceramic

Resistors

1 330Ω 0.25W 5%
1 10kΩ trimpot

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

LED light curtain stops garage door damage to cars

This circuit was devised to prevent damage from a motorised garage door to a 4WD vehicle with variable height air-suspension. It would also be useful for any car with a tail-gate which may be at risk when the car is close to the garage door with its tail-gate open. Either way, the circuit effectively provides an infrared "light curtain" at the rear of the vehicle. If the "light curtain" is interrupted by the rear of the car or its tail-gate, the garage door will be inhibited from closing.

Because the top section of the door could hit the car in variable positions, the light curtain is actually mounted on the garage door itself. The light curtain uses a single infrared LED but depending on its configuration, more LEDs can be employed from the same transmitter which is based on a 556 dual timer.

The first section of the 556 is an astable oscillator running at 1kHz with close to a 50% duty cycle. Its output gates the second section via its reset input at pin 10. This is again an astable but it runs at 38kHz, adjustable by trimpot VR1. The result is a continuous stream of 38kHz bursts which are modulated at 1kHz; 0.5ms on, 0.5ms off.

The burst length is not critical and anything from about six 38kHz cycles to 100ms worth at a 50% duty cycle seemed to work reliably but a modulation frequency of 1kHz gave a satisfactory response time. The output of the second timer at pin 9 drives infrared LED1.

The "curtain" consists of one or more infrared receivers with built-in 38kHz demodulators (eg, Jaycar ZD-1952). The outputs of the detectors are ORed together by the associated diodes (D1, D2 etc) and fed to the base of NPN transistor Q1. If all of the infrared detectors are receiving a 38kHz signal, their outputs will be low. However, if one of the IR detectors is blocked by the car, its output at pin 1 will be a 1kHz square wave and this will pulse turn on transistor Q1.

Q1 will feed a 1kHz square-wave to the threshold input of the first timer of IC2 but if any receiver loses the signal from the transmitter then its output will go high and stay high. This means that the signal to the timer will go low and stay low. This timer is unusual in that its operation is inverted to the normal sense of monostable operation, ie, it accepts positive-going triggers and delivers negative-going output pulses. The function of the trigger and threshold inputs is reversed and the timing is referenced to the supply voltage rather than ground.

Its output is normally high and therefore so is the voltage on the timing capacitor. When triggered by a positive-going input pulse, the timing cycle begins. The timing period is about 0.75ms; long enough to ensure it is ready for the next positive-going 1ms trigger pulse. It should not be shorter than 0.5ms as it would be re-triggered because the input will still be high. The open-collector discharge function follows the output and is connected to the discharge pin of the second timer.

This is a conventional monostable, triggered by the negative-going output pulses from the first timer. Its timing period is approximately 3ms and during normal operation the first timer is being continuously triggered and timing out, so that the timing capacitor of the second timer is being clamped by the discharge output of the first timer during its timing period. This means that the voltage on the capacitor of the second timer never reaches the 2/3Vcc threshold. Its output therefore is high because it has been triggered, but also stays high because it can't time out.

However, if the beam to an IR

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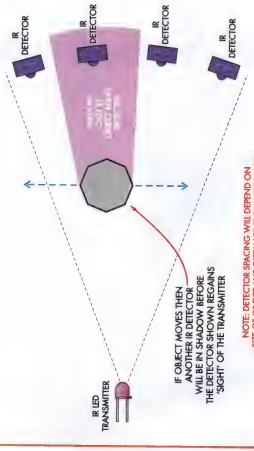
Alan Chamberlain is this month's winner of a $150 gift voucher from Hare & Forbes

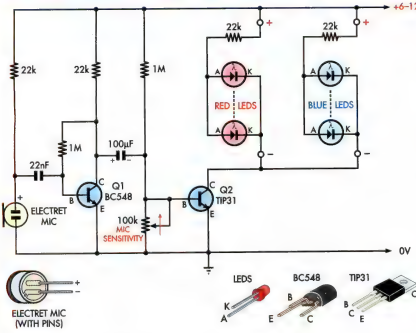
receiver is broken, then the trigger pulses to the first timer cease and its output remains high. This means that the second timer's timing capacitor is now free to charge to the 2/3Vcc threshold level and the timer times out after three missing pulses. The timer output then goes low and the reed relay closes its contacts, signalling a broken beam and an object (car) in the way.

If the beam is re-established, everything goes back to normal and the output relay de-energises. If faster response times are required then the 1kHz modulation frequency can be increased and it may be an advantage to use the Jaycar ZD-1953 IR receiver rather than the ZD-1952. The receiver timing intervals would have to be adjusted accordingly.

If you only require a broken beam detector then you can certainly use only one IR LED and one IR receiver. The isolating diode can also be deleted, as can the 120kΩ pull-down resistor.

Alan Chamberlain, Charlestown, NSW.





Simple circuit modulates LEDs to music

It's nearly Christmas time and soon you will start seeing houses decorated with lights and some will even blink synchronously with the music beat from an audio source. This circuit allows you to achieve a similar result on a much smaller scale, using cheap LED Christmas lights (typically $2 to $5) that come with 15 to 20 LEDs in parallel in a variety of colours.

The circuit can be used to decorate a small Christmas tree or a display that blinks in time with the music or sound that is picked up by the microphone.

The prototype was based on blue and red sets of parallel LEDs. The 3V AA battery holders with built-in slider switches were cut off (to be saved for other projects) and the LED strings connected to the power source via a 22kΩ resistor which provided a suitable LED brightness level.

The circuit can run off any supply from 6-12V DC. A 9V battery kept the circuit operational for about six weeks; just the right length of time for the Christmas period.

Only two transistors are required. Q1 functions as simple preamplifier stage for the electret microphone which is biased by a 22kΩ resistor. The preamp output is AC-coupled via a 100µF capacitor to a voltage divider comprising a 1MΩ resistor and 100kΩ potentiometer VR1 which functions as crude gain control for the following stage, Q2. No heatsink is required for Q2 since the operating currents are low.

Owen Winter,
Tarragindi, Qld. ($50)

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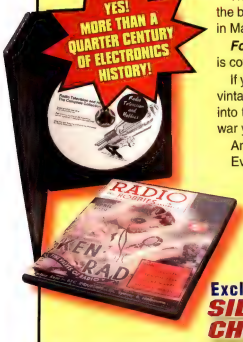

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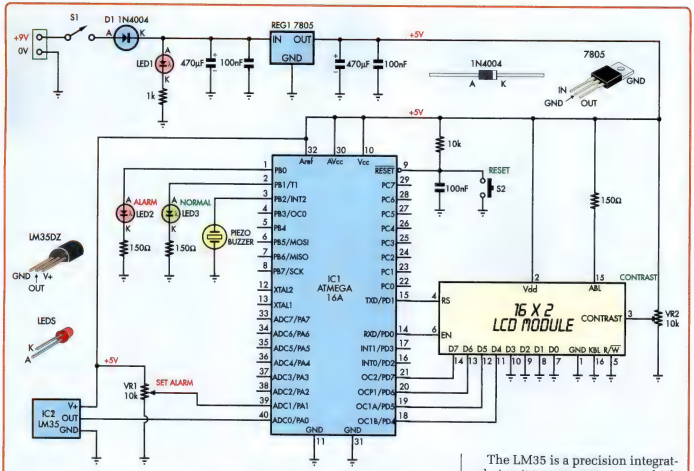

Celsius/Fahrenheit digital thermometer with alarm

This Celsius-Fahrenheit digital thermometer is based on an LM35 temperature sensor/transducer (IC2) which feeds one of the ADC (analog to digital converter) inputs of an Atmel AVR ATmega16 microcontroller, IC1. The micro is programmed to display Celsius and Fahrenheit degrees on an alphanumeric 16x2 LCD module and to set the alarm system.

The alarm system employs a normal LED (LED3), an alarm LED (LED2) and a piezoelectric buzzer, the latter driven from its pin 6 output. The alarm temperature threshold is set by VR1, there being no need for set/reset and up and down buttons.

The first line of the LCD shows the current air temperature in Celsius and Fahrenheit degrees and the second line displays the alarm temperature in Celsius and Fahrenheit degrees, which is adjustable between 0-100°C or 32-212°F. The second line of the display and the trimpot also serve as a Celsius to Fahrenheit or Fahrenheit to Celsius converter. The internal oscillator of the chip is set to 1MHz.

The LM35 is a precision integrated-circuit temperature sensor which is calibrated directly in Celsius and its output voltage is linearly proportional to the Celsius temperature. It provides typical accuracies of ±0.25°C at room temperature. As it draws only 60µA from its supply, it has less than 0.1°C self-heating in still air.

The scale factor of the LM35 is +10mV/°C. In this circuit, the temperature range is 0-100°C. Thus, the voltage of the sensor varies between 0V for 0°C and 1V for 100°C.

The software, Thermometer.bas, can be downloaded from the Silicon Chip website.

Mahmood Alimohammadi, Teheran, Iran. ($65)

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Vintage Radio

By John Hunter

Above: an assortment of vibrators. The large box shaped unit with multiple contacts was used in a high power 60Hz inverter.

A practical guide to vibrator power supplies

Most people think switchmode power supplies are a relatively recent technological development. Well, they're not. They were devised long before transistors were developed. Vibrator power supplies in valve car radios were the first switchmode power supplies and they were devised way back in the early 1930s. Here's a quick run-down on the various vibrator types that were used, together with details on how to service and replace them.

BEFORE VIBRATORS were developed, the first valve car radios relied on a motor-generator to provide the HT from the car battery. The vibrator was a big improvement – tiny and highly efficient.

This article is focussed mainly on servicing these apparently simple devices. To the vintage electronics enthusiast, a vibrator power supply can be a source of frustration. All too often, what is seemingly a simple circuit fails to operate reliably, if at all. However, with a proper understanding of circuit operation, this need not be so.

The subject of vibrator power supplies is an extensive one and it is impossible to cover all aspects here. Interested readers should therefore make use of the references listed at the end of this article. In particular, the September and October 2003 issues of SILICON CHIP are recommended for those unfamiliar with the topic.

What is a vibrator?

Basically, a vibrator is an oscillating mechanical switch. It allows a transformer to be used with a DC supply by providing the DC-to-AC conversion necessary to drive the transformer. The transformer's AC output can then be used directly or it can be rectified if DC is required.

The best known vibrator application is in a valve car radio power supply. Such supplies typically produced around 200V DC when powered from the car's battery. Another application is where 240VAC appliances are operated in a vehicle or from a DC home-lighting plant.

Background

The first generation of car radios used the car's battery for the valve heaters but high-voltage "B" batteries (typically 135V) had to be provided for the plates and screens. However, it's easy to imagine the frustration of having to continually replace expensive "B" batteries while a fully-charged 6V

This photo shows the internal parts of an Oak series-driven, non-synchronous vibrator. Note the coil contact adjusting screw on the righthand side.

Built by the author, this 12V DC to 240VAC power supply uses an Oak non-synchronous vibrator and is based on the circuit shown in Fig.1.

or 12V battery was already in the car.

So in 1932, P. R. Mallory & Company (of later Duracell fame) produced the first commercially-available vibrator power supply for car radios, under the "Elkonode" trademark. Its compact construction and quiet operation virtually eliminated motor generators and "B" batteries from car radios almost overnight.

Other manufacturers, such as ATR, Radiart, Utah and Oak, were also prominent players, each contributing to improvements in the technology. The first Mallory design was essentially a buzzer interrupting the primary current in a transformer at a frequency of 300Hz. A gaseous rectifier then provided 135V DC from the transformer secondary. Utah subsequently introduced full-wave operation which quickly became standard. A frequency of 100-150Hz also became the standard for most radio vibrators.

Series & shunt drive

Australian vintage radio restorers are fortunate in that most set manufacturers used an Oak vibrator. This type of vibrator was patented in the USA in 1934 and was made locally by AWA's MSP (Manufacturers Special Products) component division. Also commonly found are Ferrocart branded vibrators which were an Electronic Industries Ltd product and which were largely confined to their own brands such as Air Chief and Astor.

The importance of this is that the Oak vibrator has a series-driven coil. That is, the driving coil is switched by its own low-current contact. One advantage of this is that the reed will vibrate independently of the condition of the transformer switching contacts. Fig.1 & Fig.2 show how the reed is driven.

By contrast, the Ferrocart type of vibrator shown in Fig.3 is shunt-driven. This is the most common vibrator type used overseas. The driving coil shares the transformer switching contacts and while its simpler construction might seem advantageous, it will not start if there is any oxide or film on the contacts. And until it starts, the contacts won't be cleaned by the wiping action so it's a catch 22 situation.

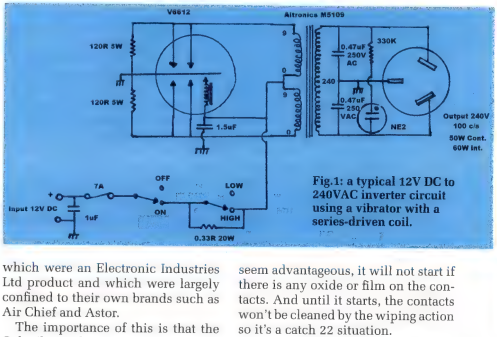

Fig.1: a typical 12V DC to 240VAC inverter circuit using a vibrator with a series-driven coil.

Due mainly to its separate driving contact, the Oak/MSP type has turned out to have exceptionally good reliability. Even if the transformer contacts are worn or out of adjustment, it will start and produce an output. Shunt-driven types, on the other hand, simply fail to operate.

DC-to-AC conversion.

The inverter circuit of Fig.1 is one of my own designs but is typical of those that existed in the era. In this case, the vibrator has extra paralleled

This wartime advertisement shows the inner workings of an English vibrator that was based on Oak's patents.

contacts to obtain an increase in power rating. This type is known as a "dual interrupter".

However, contrary to expectation, the rating is somewhat less than double. This is because it's impossible to ensure the paralleled contacts open and close at exactly the same time over the life of the vibrator. In practice, better current sharing is obtained if the transformer has two primaries, switched by the individual contacts.

Because a radio-type vibrator is used, the output frequency is 100Hz but for many loads this is unimportant. Larger inverters generally use a 50Hz vibrator.

The 120Ω primary damping resistors help reduce RFI (radio frequency interference) and contact sparking. They do not usually cause trouble as they are low-value resistors which do not drift, as do old carbon resistors in the kΩ and MΩ range. What's more, not all designs include them.

Note also that any paper capacitors on the low-voltage side of the vibrator can generally be left in place because any leakage will cause no ill effects. In this circuit, if the 1μF and 1.5μF RF filter capacitors were leaky, all that would happen would be a small increase in the current drain.

Conversely, on the secondary side of the transformer, the buffer capacitor (here shown as two series-connected 0.47μF capacitors) is critical. Leaving an original paper capacitor in circuit here is a recipe for damage. Because of the voltage it is subjected to, leakage is not only very likely but also destructive. If left in place, a leaky buffer capacitor will overheat the vibrator contacts and ruin their spring temper.

This means that any paper buffer capacitors should be replaced as a matter of course. The ideal kind to use is a high dV/dt type, given the sharp risetime of the waveform. It also needs to be of sufficiently high voltage.

The "KP" series of polypropylene capacitors available from WES Components are a good choice. It is possible to use other types in some circuits but only with a good understanding of the particular operating conditions.

The purpose of the buffer capacitor is to form a tuned circuit with the transformer at the vibrator's frequency, reducing its inductive effect and thus preventing contact arcing. Thus, it is important not to deviate from the original value. Incorrect tuning results in increased current consumption and short vibrator life.

Some texts claim that it is impossible to eliminate all contact sparking but my own experience is to the contrary. If the power supply is properly designed, no contact sparking will be visible at all. These power supplies are characterised by their ease of RFI filtering and even after 60 years, the vibrator contacts can still look like new.

Non-synchronous conversion

Having produced AC at the transformer's secondary, any standard rectifier circuit can then be used to produce the DC required for valve plates and screens. Conventional rectifier valves such as the 6X4 are typical but the 0Z4 gas rectifier was popular in American designs. By contrast, the 0Z4 was not manufactured in Australia, so few local designs used it.

The power supply circuit used in the AWA 946AZ car radio (Fig.2) was typical practice. It uses an Oak "non-synchronous" vibrator, as shown in one of the photos. (Editor's note: non-synchronous vibrators are also referred to as "asynchronous").

On the primary side of the transformer, L6 & L7 are chokes for further RFI filtering. Paper capacitor C27 needs to be replaced as a matter of

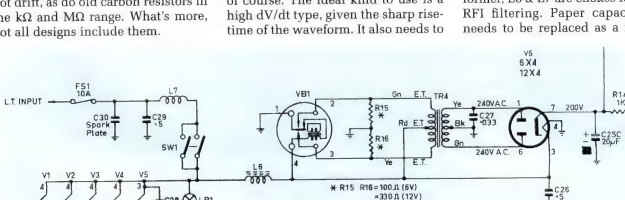

Fig.2: the power supply circuit used in the AWA 946AZ car radio also used an Oak non-synchronous vibrator. Capacitor C27 in this circuit should be replaced as a matter of course to prevent contact damage (see text).

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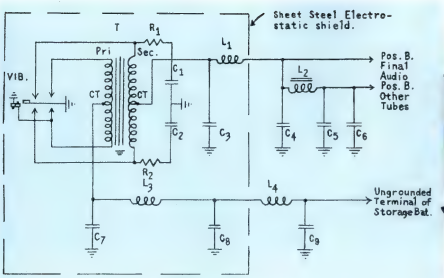

Fig.3: a Ferrocart circuit for a synchronous vibrator. Note the extra set of contacts which rectify the transformer's secondary winding output.

course (as detailed above), while C26 & C29 will cause no ill effects if leaky and can be left in position.

The replacement parts must be connected to the same tags as the originals, the earth connection points of the capacitors being particularly important. It is tempting with newer, smaller components to connect one lead to a closer earth tag, for example. However, because of circulating currents in the chassis, this new earth point may actually increase RFI. A lot of design work goes into the layout of an interference-free power supply.

Note that the vibrator symbol on Fig.2 shows a second winding on the driving coil which is short-circuited. Its purpose is to prevent arcing at the coil contact by slowing the rate of magnetic flux collapse when the contact opens.

The waveform of the transformer secondary across C27 is shown in Fig.5. Note that the input polarity is unimportant as the rectifier will automatically produce correct polarity at the output. This meant that in an era where positive-earth vehicles were just as common as negative-earth vehicles, a radio could be installed in either type of car without modification.

By the way, failing to include a fuse in the supply input lead can lead to a damaged transformer or vibrator if the buffer capacitor fails or if the vibrator contacts stick because of overload.

Synchronous conversion

Early on in the vibrator's development, it was realised that a second set of contacts synchronised with the primary contacts could be used for rectification. This is known as a "synchronous" vibrator. In simple terms,

This view inside a Ferrocart synchronous vibrator clearly shows the extra set of contacts that were used for rectification.

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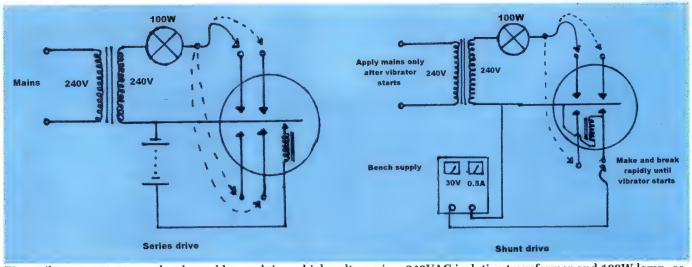

Fig.4: vibrator contacts can be cleaned by applying a high-voltage via a 240VAC isolating transformer and 100W lamp, as shown here (see text for details). DO NOT attempt this procedure unless you know exactly what you are doing.

the secondary contacts close at the same time that a conventional diode would conduct.

Fig.3 shows a synchronous circuit using a shunt-driven vibrator. If the secondary contacts are imagined as diodes, with their cathodes connected to the winding and their anodes earthed, it can be seen that this is a conventional full-wave centre-tap rectifier circuit. However, unlike the non-synchronous circuit, either the secondary or primary winding connections must be reversed if the output polarity is incorrect.

Again, buffer capacitors C1 & C2 will need to be replaced if they're original paper types. Generally, the secondary damper resistors, R1 & R2, will be OK because they are low-value types. They still need to be checked though, because if either C1 or C2 shorts, these resistors act as fuses, leaving the vibrator running with no buffer capacitance. However, the user is left none the wiser as the radio continues to play, albeit with an arcing vibrator headed for an early demise.

The additional rectifying contacts are visible in the accompanying photo of a Ferrocart vibrator. It's suitable for use in the circuit shown in Fig.3.

A variant of the synchronous vibrator is the split reed type. Here, the reed is split into two sections so that the primary contacts do not share a common earth with those of the secondary. This allows a negative bias supply to be obtained by earthing the secondary reed through a back-bias resistor.

Synchronous vibrators were preferred for domestic radios because the inefficiencies of a thermionic rectifier were eliminated – an important consideration when the battery has to be charged off-site.

Old is new again

It is no coincidence that when presented in a purely solid-state form, the circuits described closely resemble a modern switchmode power supply. All modern DC-DC converters use the same principles. However, instead of a mechanical contact interrupting the DC input, a bipolar transistor, Mosfet or IGBT is used. Likewise, because of the inductive load, steps have to be taken to prevent destructive voltages appearing across the switching device.

In modern switchmode supplies, rectification of the secondary voltage is usually taken care of by silicon diodes. In synchronous switchmode supplies, the rectification is taken care of by Mosfets or IGBTs which are "synchronised" with the input switching devices.

Of course, input and output filtering is still required, just as in the mechanical vibrator supplies, to prevent radiation of RFI. The only fundamental difference in operation is that the vibrator supply is operating with a fixed duty cycle and is therefore unregulated.

Vibrator faults

After many years of disuse, an insulating film builds up on the contacts. Some literature describes it as due to oxidisation of the contact metal but my observation is that it could also be a decomposition by-product (one source suggests sulphur) released from the sponge rubber that's used to line the inside of the can.

Because of this film, the most usual result when powering up a long-disused vibrator is that, if it's a series-drive type, it will vibrate but produce no output or only a half-wave output. Alternatively, if it's a shunt-drive type, it won't start at all. Even NOS (new

Further Reading

Silicon Chip:

(1) January 2001 – Operatic Mignon 32V Mantel Radio.
(2) November 2002 – AWA 532MF 32V Mantel Radio.
(3) September 2003 – Vibrators Pt.1
(4) October 2003 – Vibrators Pt.2.
(5) March 2005 – Astor AJS Car Radio.
(6) June 2008 – DC to AC Inverters Pt.1.
(7) February 2008 – DC to AC Inverters Pt.2.
(8) May 2015 – AWA 523-M 6V Mantel Radio.

Radio & Hobbies, September, October & November 1944: A Study Of Vibrator Power Supplies.

Electronics Australia, October 1975: Solid-State Vibrator Circuit.

old stock) vibrators straight out of the box can exhibit this sort of behaviour.

At this point, most restorers remove the can to clean the contacts. With the Oak type, this is easily done; it's just a matter of removing a spring clip at the base and desoldering an earth tag. Unfortunately, it's impossible to open crimped-can types without some disfigurement.

Cleaning the contacts

Often though, it isn't necessary to open the can to clean the contacts. For many years now, I've applied a high voltage to the contacts to break down and burn off the film. This method requires a 240VAC isolating transformer and a 100W incandescent light bulb, connected as shown in Fig.4. A battery or DC power supply is also required to drive the reed.

WARNING: to ensure your safety, you MUST USE an isolating transformer (see Fig.4) and no connections or parts of the vibrator or DC supply should be touched while power is applied. The transformer isolates the vibrator and the external DC power supply from the mains and also ensures that if the DC supply's output is earthed, then the mains will not be shorted to Earth (ie, the transformer is NOT an optional extra). Finally, DO NOT carry out this procedure unless you know exactly what you are doing.

For a series type vibrator, with the driving coil powered up, the reed should start vibrating and the current drain will only be a few hundred milliamps. Next, 230VAC is applied to each contact in turn, via the 100W lamp from the isolated supply. The lamp limits the current when the film burns off and the contacts start working, and provides a visual indication that the process has been successful.

Once the contacts are functional, the light bulb will appear to flicker at a slow rate, because of the difference between the vibrator and mains frequencies.

If the reed won't vibrate, the can will have to be opened for further examination. The usual cause of the problem is a broken solenoid wire or the contact screw might need adjustment.

Shunt-drive vibrators require a different set-up. In this case, I use a 30V bench supply, current-limited to 500mA, to try to get the reed vibrating (ie, before high voltage is applied to the other contacts). Applying the current to the coil will force the reed to swing over to the contacts. By rapidly making and breaking the 30V connection, the driving coil will develop a high-voltage back-EMF which is enough to break down the film. It can take quite a few minutes before it breaks down but this procedure is preferable to opening a crimped can.

It is also sometimes possible to force the reed to vibrate using another 100W bulb instead of the 30V power supply but only if the reed frequency is a harmonic of 50Hz.

Once the contacts function, the vibrator will start. Obviously, the power supply must be current limited as it is short circuited when the contacts make. With the vibrator buzzing, the other contacts can then be cleaned with high voltage as previously described. Incidentally, the driving coil for shunt-driven vibrators normally operates at twice the supply voltage because of transformer action, so the application of 30V for a short period is not harmful.

Do not fall into the trap of a vibrator operating in a half-wave mode. Just because it buzzes and produces an output, all may not be well. Symptoms of half-wave operation include a low output voltage and arcing in one set of contacts.

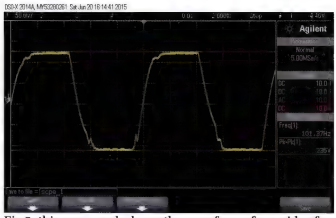

Fig.5: this scope grab shows the waveform of one side of the power transformer secondary in the AWA 946AZ car radio. Note that the input to the scope was attenuated 2:1, so the actual voltage is twice that shown.

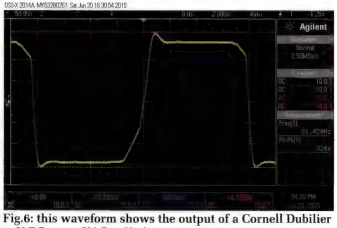

Fig.6: this waveform shows the output of a Cornell Dubilier 12V DC to 115VAC 60Hz inverter.

This occurs when the other set of contacts is not functioning; often because of a dry joint or because the vibrator socket is faulty. The output waveform will be asymmetrical. The trap here is that the radio will work in this condition but the user will be oblivious to the damage occurring to the contacts.

Contact adjustment

The contact spacing adjustment is a compromise between output voltage and the possibility of sticking. The less "dead time" (and thus spacing) there is between one set of contacts opening and the other closing, the higher the output voltage. Conversely, if they are too close together, contact sticking can become a problem.

If the output voltage is low and the other components are known to be OK, chances are the contact spacing needs to be readjusted. In the case of synchronous types, the secondary contacts are set to close just after the primary contacts and to open just before them. This eliminates the arcing that would otherwise occur because at these times, the voltage across the contacts is at a minimum.

Makeshift contact adjustments can be done by measuring the transformer secondary voltage and adjusting the primary contacts to bring this up to specification. Likewise, the secondary contacts can be adjusted to produce

Vibrators were most commonly used in car radio power supplies, such as in this AWA 946AZ.

the maximum B+ voltage without any sparking.

A crude method that can be used to set dual interrupter contacts is to temporarily reduce the buffer capacitance enough to just make the contacts arc. The first set of contacts is then set as per a non-synchronous type, while the second set of contacts is set so that they arc by the same amount as the first.

That said, an oscilloscope is really essential for proper vibrator adjustment because it reveals the contact condition, timing and operating conditions in a manner that meters and visual inspection cannot.

Can lining

If you have to replace the foam rubber can lining, it's important for the actual vibrator assembly to be allowed to "float". Having it held tightly changes the operating conditions – clearly visible on a scope. Early vibrators use a loose wrapping of felt and this is a satisfactory alternative if suitable rubber material cannot be obtained.

Transformer problems

If one half of the transformer's secondary has gone open circuit, the good half can still be used by using a bridge rectifier to replace the existing rectifier valve or the vibrator's secondary contacts (if fitted). The buffer capacitor must, of course, be connected across the good half but note that unless there was originally only one buffer capacitor across one half of the winding, its value has to be increased.

If the transformer has failed completely, a common 240VAC power transformer can be used as a replacement. Some types work better than others but by far the best type to use is a toroid.

In this case, because the primary (240VAC) winding isn't centre-tapped, a bridge rectifier must be used. In addition, because the duty cycle will be less than 100%, the turns ratio needs to be higher than first thought. For example, a 9-0-9V low-voltage winding is required to provide a 240VAC output from a 12V supply.

If the transformer is changed, the buffer capacitor may need to also be changed. In fact, it must usually be increased if a 50Hz transformer is used.

The ideal buffer capacitor is one that results in minimum primary current, together with an output waveform that has no overshoot on the rising edge or excessive slope on the trailing edge. Nor must there be any contact arcing. The operation of the buffer capacitor should be checked with the vibrator in its can, as there can be a slight change in duty cycle and frequency after it is enclosed.

Substituting vibrators

If a synchronous or dual-interrupter vibrator is being used to replace a non-synchronous type, it's a good idea to parallel the unused contacts with the existing primary contacts. Conversely, substituting a non-synchronous vibrator in place of a synchronous type can only be done if a valve or solid-state (diode) rectifier is used to replace the secondary contacts.

Note also that a low-voltage series-driven vibrator can be used in a higher-voltage circuit provided a resistor is installed in series with the driving coil. For example, you can use a 27Ω 5W resistor for 6V Oak vibrators operating from a 12V DC supply.

Finally, if the new vibrator operates at a different frequency, the buffer capacitance needs to be checked. Also, if the vibrator is mounted horizontally and is substituted with a different type, ensure that the reed is in the vertical plane, otherwise there might be gravitational bias towards one set of contacts.

High efficiency

Many restorers have fallen into the trap of assuming a vibrator is merely a buzzer converting DC to AC. This leads to frustration and ultimately the installation of an electronic replacement.

In fact, the electromechanical vibrator is a precision component with extensive research and development behind its design. Because a vibrator is an on/off switch with minimal voltage drop, the efficiency of a well-designed circuit is high (the inverter in Fig.1 has an efficiency of 83% with a 40W load). In fact, most of the power loss is from the transformer, driving coil and damping resistors – not the vibrating contacts.

Because everything from the regulation of the vehicle's charging system to the circuit design affects vibrator life, manufacturers don't usually specify what this is. So just what kind of life can we expect?

Well, various 1930s sources do make such claims as "5000 hours" or "four times the life of the rectifier tube in the set". Having collected nearly 100 vibrator-powered items over the last 35 years, I have never had to replace a vibrator unless it was missing to begin with. Some of my radios and inverters have been in daily or weekly use for the last 10 years (powered from a 12V solar supply) and all have operated without fault.

It's interesting to note that AWA was still producing a vibrator-powered car radio (the 946AZ) as late as 1965, as shown in the accompanying photo. The reliability of the Oak vibrator and AWA's attention to design detail ensured that this radio was competitive with its transistor counterparts of the era. Indeed, many of these radios operated without fault well into the late 1980s.

Clearly, when understood and operated correctly, vibrators can be just as reliable as other components. SC

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Mains voltage monitor wanted

I have been looking on your website for a mains voltage monitor. I would like to monitor the AC output of my variac, without needing to unplug it and use my multimeter to check it. The variac has an analog panel meter on it but I don't want to rely on that alone. Sensing the AC current would be nice too.

I figured this may also be useful for some existing projects, like a mains limiter that ensures the mains is set to 230VAC. Having digital readout of the voltage would be nice and easily retrofitted in the kit. This could be added to most kits that use mains power. Do you already have something that I can use? (M. V., Gladstone, Qld).

● We published an Appliance Energy Meter in July and August 2004. This shows the power being drawn at any time. It does not show the voltage but the concept may be useful in that you could build a similar device that incorporated the transformer power supply and used a 9V regulator instead of a 5V regulator. This could be used to power a cheap multimeter set to read AC volts. This multimeter could be housed inside the clear lid box and permanently wired to measure the mains voltage.

While a meter could also be used to show current, this does not show the full information since power factor is important. See the Appliance Energy Meter article for more details on current versus power factor and how this affects the real current flow.

Stopping interference from a light chaser

I recently completed building the Portable Stereo Music Centre project (SILICON CHIP, February 2014) using a good-quality Alpine car radio. The system works extremely well and the sound quality is very good. However I decided to add some "BLING".

I completed the Jaycar 10-LED Light Chaser Kit (Cat K-8064) and installed the LEDs around the front of the radio box. Both the radio and the chaser run off a 12V SLA battery. The problem is that when I turn on the chaser there is heavy interference on the radio.

To solve the problem I was planning on mounting the chaser PCB in a diecast aluminium box and running shielded cable to the individual LEDs. Would this help or can you offer another suggestion? (K. J., via email).

● We would be inclined to see if you can modify the circuit of the chaser to see if you can "shut it up". This might be achieved with a 470µF 16V capacitor across the DC supply leads to the chaser board. And then it might be worth adding capacitors (say 0.1µF) across the output leads to the the chaser LEDs. If that doesn't work, try threading the common return lead for the Chaser LEDs through a large ferrite toroid, as many times as you can.

Remote control of induction motor speed

I'm about to set up the 1.5kW Induction Motor Speed Controller for use on my Hafco milling machine which I am converting from a single phase 4-pole to a 3-phase 6-pole motor. I would like to mount the controls, eg, speed, run, reverse, stop and the three LEDs in a remote box, less than 0.5m from the inverter unit.

My question is would it be OK to use a common earth return for all these components? That is, the low voltage earth associated with T2.

If it's OK to use a common earth re-

Difficulty Obtaining Correct Inductance For Class-A Amplifier

I am currently building the 20W Class A amplifier modules from your May-June 2007 issues. However, I am having trouble with the actual value of inductor L1.

I have followed the winding instructions perfectly using 1mm enamelled copper wire with 25.5 turns on an 11.8mm ID bobbin. However the value of inductance that I measure with my SILICON CHIP L/C meter is 0.68µH. I am not sure if my meter is able to measure that low or maybe I have another problem. I have measured other inductors I had on hand, from 47µH to 470µH, and all seem OK.

Is there another way I can confirm the value? Any help would be appreciated. (P. O,, via email).

● If you have wound on the correct number of turns, you will have very close to the required inductance. Perhaps your inductance meter is a bit off when measuring very low inductances. Despite this, we don't think it should be necessary to purchase another inductance meter – you might be able to see what is wrong with your present one. If you have a signal generator and scope you should also be able to do a simple parallel resonance test to confirm the inductance value.

Connect the inductor and the 150nF capacitor from the output RLC network in series and feed in a sinewave signal via a 1kΩ resistor. Measure the voltage across the series RC combination while you sweep the frequency over a range from 20kHz to 200kHz (or thereabouts). There should be a pronounced dip in the voltage at close to 160kHz.

The exact resonance figure will depend on the actual value of the 150nF capacitor which probably will have a manufacturing tolerance of ±10%. Provided the resonance frequency is close to 160kHz, the inductor will be OK.

Hybrid Solar Inverter Wanted

Your report on hybrid solar systems in the October 2015 issue resonated with me. I'm in the process of adapting a 2500VA uninterruptible power supply to serve as a 48V DC-230VAC inverter, to charge a 48V battery bank with solar panel surplus energy. The UPS will then invert the 48V to 230VAC for domestic consumption after dark. I'm only using the UPS because it has a high power inverter within.

The UPS in question was made by Holec, a Sydney-based company, and I've had to reverse engineer the device to obtain a schematic circuit – no mean feat! The inverter consists broadly of a 50Hz PWM generator which switches Darlington transistors connected between the 48V supply and a 50V-to-230V step-up transformer. All the circuitry uses discrete components and the Darlington transistors are rare and expensive.

It doesn't appear that SILICON CHIP has ever published a UPS project and with PWM generators now available in a single IC and IGBT or power MOSFETs quite inexpensive, a modern reincarnation should be feasible. Pure sinewave UPSs up to about 2500VA are now coming on to the market but they are priced at over $1200 at the high end of the range.

So I want to encourage SILICON CHIP to do a project on high-power PWM pure sinewave inverters which could be applied either to off-grid solar systems or to UPS systems. Perhaps there are other possible applications as well.

I should think there would be significant interest amongst your readers for a state-of-the-art UPS design below this price point. Not only could the basic design provide for a range of UPSs of varying capacities, but it could also serve as the core of a pure sinewave inverter for use within hybrid solar systems.

A number of SILICON CHIP projects have used PWM controllers in various configurations, so it would appear that your designers would be well able to come up with reliable designs. Also, there is a growing supply of surplus solar inverters which might serve as a useful source of high-current devices such as transformers and switching transistors. (R. F., via email).

● We assume you have seen our 1.5kW Induction Motor Speed Controller that was published in the April, May & December 2012 issues. This runs from an input of 230VAC or about 320V DC so could run from a typical domestic solar panel array.

However, what you seem to be asking for is a hybrid inverter system, much like that described in the October 2015 issue. That would require an MPPT inverter charger to charge the 48V batteries from the 340V or more from standard solar panels and then act as a standard sinewave inverter to supply 230VAC from the batteries after dark.

That would be a major step up in complication and engineering from the Induction Motor Speed Controller project. In blunt terms, we ain't gonna do it.

turn at the remote box end should I decouple the earth to the 3.3V supply with a small capacitor, say 100nF? I propose using a 9-way shielded cable, eg, Jaycar WB-1578, for the interconnection, with the shield connected to an earth at the inverter end. Is shielding necessary? If so, should I connect the shield to the mains earth or the low voltage earth?

The remote box will also have 24VAC present as part of the milling machine's control circuit. Any problems with this? I can isolate it using some Presspahn. (B. P., via email).

● While you could use a single ground connection, it would be better to have two: one connected only to the speed pot and one for the rest of the controls. This way, when LEDs and switches change state, it won't affect the speed setting read by the unit. You shouldn't need a bypass capacitor in the control box; all the remote components are effectively linear loads.

Shielding is probably a good idea as otherwise, strong interference could affect the speed setting. You could use the shield connection as the second ground return if necessary. In theory, connecting it to both the isolated ground and mains Earth would be a good idea, as earthing it would make the shielding more effective and may also provide an extra safety margin in case wiring comes adrift inside the unit (something you should obviously strive to avoid!).

Naturally, you should be very careful when wiring the unit up, to ensure that none of the wiring from the mains side could possibly touch any of the low-voltage/isolated wires, even if someone pulls very hard on the remote control box. That means the remote cable will have to be very well anchored.

We don't think the presence of 24VAC is much of a hazard to your health although you may want to isolate it on the basis that it could easily damage the speed controller if it comes in contact with any of the isolated circuitry.

Set-and-forget audio mixer

Most of us have many audio devices connected to our main sound system. These devices all have their own on/off and audio level switches and typically have different impedances and audio level ranges. The common way of connecting these devices is to use a switch to the AUX input, which doesn't cater for the different impedances and signal levels, and also requires switching whenever changing devices.

I would like a mixer kit with at least four stereo inputs that could be set for impedance and level, and forgotten. That way, I'd only need to switch the audio from the devices, without having to play with the main volume when changing devices. The kit should be daisy-chain connectible, ie, with two kits you could have seven inputs!

Finally, the kit should be short-form as input plugs would vary greatly. (Y. B., via email).

● We have produced quite a few mixers over the years but most have been mono. We published two stereo mixers in 1996: a Surround Sound mixer, in January & February, which really would not suit your application, and an 8-Channel Stereo Mixer in November & December, which was far too large and complicated for your application.

That is a drawback of all mixers, in that, if you want more than just the very basic facilities, they do become quite complicated. Also, you will find that most mixers have inputs for microphones, pan controls and other facilities which evidently you don't need.

If you have a look at the stereo mixers which are available on the internet, you will rapidly conclude that finding the exact mixer to suit a particular application is almost impossible.

For the same reason, we would be reluctant to design and publish a mixer to suit your application because it is likely to have limited interest for other readers whose requirements are likely to be quite different to yours.

Having said all that, do you really need such a mixer? Given that all channels of your proposed mixer would be "open" at all times, the resulting sound quality would not be as clean and noise-free as you might wish and it would be likely to pick up unwanted RF interference, as well. Daisy-chaining would make it even worse.

By comparison, once you have selected a program source to listen to, you may or may not need to adjust the main volume. Also consider that many program sources have their own remote controls, so tweaking the volume setting is not an onerous task.

Queries about 4-terminal measurements

With respect to the Milliohm Meter Adaptor for DMMs, (Silicon Chip, February 2010), when using the 4-terminal measurement method on a resistor which is in circuit – and so can't be brought up to the Force terminals – is the resistance of the two leads and clips joining the Force terminals to the resistor included in the value shown on the DMM? Or are these resistances somehow "cancelled out" so that only the resistor value is shown?

It is a great piece of kit, by the way, with very clear instructions. (A. R., via email).

● When you are making a 4-terminal measurement on a resistor "in circuit" with the Milliohm Adaptor for DMMs, the resistance of the leads between the Force terminals and the resistor are not included in the measurement, provided that the Sense terminals are connected directly to the ends of the resistor being measured (via the Sensing leads).

That's the whole idea behind making a 4-terminal measurement; the sensing leads pick up the voltage drop of the resistor itself, with the Force leads being used purely to convey the accurately known Force current to the resistor.

Note that you are no longer making a 4-terminal measurement when switch S1 is in the closed (INT SENSING) position, because then the measurement will definitely include the Force leads as well as the resistor (because it's being made across the Force terminals).

Remote tell-tale for garage doors

I have recently constructed this Remote Garage Door project as described in the January 2007 issue. The assembled Tx/Rx pair, however, only partially works correctly, as follows.

The Rx always produces an unwanted error output pulse at "C" regardless of whether A, B or D are triggered at the Tx. This almost always forces the Door Open LED to remain on. All of the inputs A, B, C & D correctly produce their own Rx output, along with the Rx valid data LED flashing.

I note that your article refers to the use of the SM5162 encoder and SM-5172 decoder which are part of the items supplied by Oatley Electronics in their K190 kit. The actual parts supplied by Oatley to me are encoder = SM5262 BL (and not a SM5162 as per Silicon Chip) and decoder = SM5172 M4L. Is it likely that the "non-specified" chip pair as installed is the cause of the spurious output on C?

Can you suggest any particular fault testing that might help identify the fault apart from trying a new chip pair and or a new K190 Tx Rx pair? I have now ordered a new encoder/decoder chip pair from Oatley for starters. (M. R., via email).

● It's not easy to deduce the exact cause of your "unwanted output pulse C" problem, especially if the Rx module's valid data LED seems to be flashing correctly. It is certainly possible that the change in encoder chips (SM5162 vs SM5262BL) could result in this problem, although we can't be sure of this. It might be worth asking Oatley Electronics.

The only other possibility we can think of is that perhaps there is a faulty component or solder joint in the power-

USB Power Supply Fault

I have constructed your Mini 12V USB Power Supply (Silicon Chip, July 2015) and have run into a problem. After soldering all the components, I powered up the board and could only get 3.52V at the output.

I wonder if I have damaged any components while soldering. I soldered the regulator by hand, ie, with a dab of Jaycar silver heatsink paste. I have measured the following DC voltages: input = 12.7V, output = 3.52V. And for REG1, pin 1 = 4.24V, pin 2 = 12.44V, pin 3 = 3.52V, pin 4 = 0V, pin 5 = 4.96V, pin 6 = 0V, pin 7 = 4.37V and pin 8 = 0.57V.

Do you think I have damaged the regulator or should I look elsewhere for the fault? (D. H., via email).

● Some of those voltages do seem strange. For example, pin 6 is connected to pin 2 via a 100kΩ resistor and so you should expect 12.44V at pin 2 and close to that voltage at pin 6.

Check the solder joints carefully with a magnifying glass. You may have some joints that have not been fully formed and the pins may be in partial contact with the pads or not making contact at all. Also, check the component orientation, especially REG1.

In the text, we suggested using non-conductive heatsink paste (eg, silicone-based) because if any of it makes contact with the other pins it could cause problems. Silver-bearing heatsink paste will be conductive. Hopefully this is not the source of the problem. We are not sure if you will be able to check for resistance between pin 6 and ground without the rest of the circuit upsetting the reading but it would be worth checking.

If the heatsink paste is part of the problem, washing the component leads with pure alcohol may or may not remove any stray paste. It may also remove paste under the thermal pad too – although this seems unlikely due to the much smaller gap there.

How To Monitor Electromagnetic Interference

Could a switchmode 12V battery charger, which throws off obvious radio frequency interference (judging from my car radio's reaction) be injecting sufficient "garbage" to confuse and eventually lock out the PLC controller in a new Brivis gas heater?

I know this question is extremely vague but after two warranty call-outs to reset the board in the heater, the technician is of the opinion that mains-borne interference could be the issue and the only local suspect device is this charger.

None of our other electronic devices have been having issues. How would I go about safely checking for mains borne interference? (M. F., via email).

● You could possibly couple the mains via an X2 capacitor to a high-frequency ferrite core transformer and observe the waveform on the other winding. However, the problem would be that the reading is not calibrated and the actual frequencies that could be monitored would depend on the frequency range of the ferrite and the oscilloscope bandwidth. Typically, the ferrite would need to be suitable for RF and the oscilloscope capable of monitoring well beyond 100MHz.

The readings wouldn't necessarily indicate whether a PLC controller would be affected by the RF or not.

Perhaps the best way to determine whether the switchmode battery charger is the culprit is to check PLC operation with the charger on and off at close range. Mind you, if that proves to be the case, you might need another visit from technician.

But given that you already know that your charger is problematic, why use it at all, until you have done your best to suppress its interference? Is it in an earthed metal case? Have you tried fitting a small capacitor, perhaps 100nF, to the output leads before it exits the case? Clip-on ferrites (available from Jaycar) could also be tried on the mains input leads and the charger's output leads.

on reset circuitry in the receiver, ie, the circuitry around Q1. This might cause the symptom you describe, if Q1 was somehow unable to reset the two flipflops in IC2 when power is first applied to the receiver.

Output transistors for the headphone amplifier

I have built a couple of your HiFi Headphone Amplifiers from the September 2011 issue and find them excellent and at least comparable if not better than much more expensive commercial amplifiers.

I have a spare PCB for the amplifier and I'm curious if it is worth trying better output transistors than the old TIP series, perhaps from the MJE 150XX series, for example? Obviously, I could just go ahead and try this but thought I would seek your comments first. Any other mods since the original article would also be of interest (I am aware of the subsequent article for increased power for speakers). (D. A., via email).

● There isn't much point changing the output transistors unless you are running the amplifier at higher power levels, eg, to drive loudspeakers. In this case, using transistors with higher gain than the TIP series may provide some benefit.

A check of the data sheets for the MJE15030/31 transistors shows that they have a substantially lower gain, so will likely result in worse performance.

If you do want to experiment with different transistors, maybe try something like Sanken 2SC3852/3852A. They have the same pin-out as the TIP30/31. Overall, we don't think it's worth the trouble and you are unlikely to get any measurable improvement, let alone any audible improvement, by simply changing transistors. In fact, it is more likely that you will get an inferior result.

How to build a rotary phase converter

I'm in the the process of building a rotary phase converter. I have it working on the floor of my shed in a very crude prototype way.

I was wondering if you have or would publish an article relating to these types of converters, as any extra information in your magazine would be very helpful to me and probably a lot of other people. (D. E., via email).

● We published an article on how to run a 3-phase delta-connected motor from a single phase 240VAC supply, using capacitors, in the April 2000 issue. It was a contributed article and we do not know how effective it was.

We have not done any articles on rotary phase converters and we would be reluctant to do so as it is quite an expensive option compared to our a 1.5kW Induction Motor Speed Controller published in the April, May & December 2012 issues. This gave the option of controlling the speed of a single-phase motor or a 3-phase delta-connected 230VAC motor.

Charge controller for 12V lead-acid batteries

I am about to buy the Charge Controller kit (SILICON CHIP, April 2008) but want to make sure it can handle the current from the charger I want to use. The April 2008 article states in the main features panel that the controller suits battery chargers up to 10A rating but in the text of the article it suggests under "Charging" on page 37 that you can use a 30A charger, without actually stating it.

I have a lovely old 12V 20A charger I want to use. It's a massive metal-boxed indestructible thing that I'll be able to build the controller into. Can this project handle 20A? Or will I need to limit the current prior to the controller? (M. S., via email).

● The section under "Charging" (page 37) is concerned with the setting of the charge rate. Your 20A charger would be suitable. Typical battery chargers that deliver full-wave rectified current to the battery under charge will only supply their rated current once the charge voltage rises above the battery voltage. That is for the brief period of the sinewave shape between approximately 12V and the 17V peak as described in Fig.2 on page 31. The current is much less than the 20A rating.

Speed control for methanol/water injector

I recently purchased the 10A version of the July 1997 Motor Speed Controller kit after having installed a methanol/water injection system into my 6.5-litre turbo-diesel tow vehicle. The methanol system uses a 12V 10A mo-

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Ask SILICON CHIP

. . . continued from page 94

tor and is controlled by a boost sensor which has a cut-in adjustable between 6 and 30 psi and a maximum output adjustable between 10 and 100 psi. My problem is that in reality it doesn't engage until 8 psi, leaving me to have to push the vehicle harder to get the effect of the system.

I was hoping to be able to wire this motor speed controller in parallel with the boost controller to enable me to override the system and dial in a desired amount of methanol/water when conditions require it, while still allowing the boost switch to take over on steep climbs.

I have assembled the kit and installed it after performing the tests described in the instructions. It returned pretty much the figures quoted and gives me a range of almost zero to 12V when I turn the potentiometer (Jaycar supplied me with a potentiometer with the same value as the trimpot). The result when I flick my switch on however is full pressure which does not alter as I adjust the control and when I drive the vehicle at boost level the boost controller fails to take over.

I initially installed D2 and C3 at the motor and thought maybe this was affecting the boost controller so I tried moving them closer to the circuit board, leaving two separate parallel circuits to the motor, but this seems to make no difference.

I have retested the output voltage at the circuit board while installed in the car and get the correct results. Is what I'm trying to do not possible or do I

. . . continued on page 104

Notes & Errata

Circuit Notebook, September 2015: in the item titled "Benchtop Ignitor For Oxy-acetylene Welding", the IGBT's part number in the circuit is incorrect. It should be ISL9V5036P3. Note that this part is available from our Online Shop.

Automatic Reverse Loop Controller For DCC Model Railways, October 2012: a 10µF 16V capacitor should be added to the parts list.

Ask SILICON CHIP

. . . continued from page 103

need to do something different? I imagined it would be similar to any double switch circuit. (G. L., via email).

● It's hard to say exactly what the problem is without knowing how the existing controller works. For example, if one switches the +12V supply to the motor for speed control while the other switches the 0V connection, the motor would run at full speed regardless of the setting. That may be what you have experienced.

While not an ideal solution, you may be able to get it to work by connecting each controller to the motor via a separate pair of series diodes (at either end of the motor), to isolate the controllers from each other.

Questions on antenna designs

Thanks for the useful articles and "how-tos" with regards to the two antennas in the October and November 2015 issues of SILICON CHIP. However, something is lacking (from my perspective) and that is how you came to the dimensions that you used? Can you supply the calculations that you used? Any format is fine, including an excel spreadsheet or plain text.

The reason for asking is that I am interested in boosting reception for other bands. Also, what is the best way to boost reception in the AM band? (C. D., via email).

● Both designs were based on 5-element Yagis in the ARRL Antenna Handbook. This book is readily available on-line. The best way to boost AM reception is to use a loop antenna. We have described several, the most recent being in October 2007 and March 2005.

Preamplifier for Currawong amplifier

I am interested in building the Currawong amplifier but it sports only one input and an optional remote volume control board.

For me, one input is a bit of a nuisance, so as an alternative I purchased and am currently building your Studio Series Preamplifier, described in 2005 and 2006. My question is, can the Currawong be driven by your Studio Series Preamplifier without damage? (S. D., via email).

● If you operate both the Studio Series Preamplifier and the Currawong at the maximum gain settings, you will certainly overload the amplifier and possibly damage your speakers but would you really do that because the loudness and distortion would be extreme?

The best approach to avoiding overload is simply to set the Currawong's volume control so that no matter high you advance the volume control on the preamplifier, the loudness will not be excessive. SC

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Next Issue

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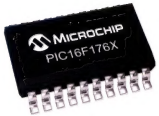

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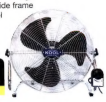

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